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ANALYSIS OF SPECIALIZED PESTICIDE PROBLEMS
INVERTEBRATE CONTROL AGENTS—EFFICACY TEST METHODS

VOLUME II

FOLIAR TREATMENTS II
(FIELD CROPS, FORAGE CROPS, RANGELAND, VEGETABLES—FIELD AND GREENHOUSE)

UNITED STATES ENVIRONMENTAL PROTECTION AGENCY

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The methods described in this report are not to be considered exclusive of other methods. Certain situations may require special methods, and new methods may be developed which improve on present ones.

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sunflowers
wheat
~~forage~~
pests of the above-listed crops
cruciferae
curcurbits
Irish potatoes
lettuce
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Environmental Protection Agency

ANALYSIS OF SPECIALIZED PESTICIDE PROBLEMS
INVERTEBRATE CONTROL AGENTS - EFFICACY TEST METHODS
VOLUME II

Foliar Treatments II
(Field Crops, Forage Crops, Rangeland, Vegetables - Field & Greenhouse)

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Environmental Protection Agency

By The

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FOLIAR TREATMENTS II
(Field Crops, Forage Crops, Rangeland, Vegetables - Field & Greenhouse)

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INTRODUCTION

The primary purpose in testing new insecticides and acaricides in foliar applications to various crops is to establish their effectiveness and usefulness. This report is concerned with testing chemicals in foliar applications to field crops, forage crops, rangeland, and vegetable crops (field and greenhouse), to establish their efficaciousness in protecting these crops from economic injury by insects and mites. In addition, test methods should take into consideration environmental involvement from such applications and the effect of pesticides on beneficial organisms. Test methods should be broad enough to provide information on the use of dosages of pesticides often required for pest population regulation in integrated pest management systems.

Foliar applications of insecticides and acaricides are usually made at recommended periods for control of the pest or pest complex present on the crop, normally during a period of pest population increase. Initially, test materials should be applied alone rather than in combination with other ingredients such as fungicides to permit evaluation of independent effects. Application equipment and methods employed should give adequate and reasonably uniform coverage approximating field practice. Test materials should be in one or more of the commercial type formulations such as wettable powder, emulsifiable concentrate, ULV, etc. It is preferable to apply pesticides at three or more dosages approximating minimum and maximum rates. Initially, new pesticides should be tested in small, replicated field plots to permit statistical evaluation of results. Large scale field trials approximating commercial use, preferably replicated, and compared with a standard treatment should be conducted to determine practicability and compatibility with the environment. Any auxiliary spray materials including spreaders and stickers used in combination with test chemicals should be named and used according to manufacturers recommendations.

The methods described herein are not to be considered exclusive of other methods. Certain situations may require special methods, and new methods may be developed which improve on present ones. With some pests several acceptable methods of evaluating pesticides are available, but only the more common ones are presented. The suggested methods are purposely kept broad to cover the wide range of conditions which may be encountered in the diverse climatic, pest and cultural conditions of different growing regions. More specific information may be obtained by referring to the literature citations.

GENERAL METHODS

The following general methods are appropriate for the evaluation of the efficacy of chemical pesticides in foliar applications (for certain pests, applications to other parts of the plant and/or soil in which they grow) to: (1) Field Crops, (2) Forage Crops, (3) Rangeland, (4) Vegetables (Field Grown), and (5) Vegetables (Greenhouse). Specific variations to these methods are identified throughout the report under the individual pest or pest group in each section.

Small Scale Field Tests

Pesticides in the early stages of development (prior to establishment of an experimental tolerance) are usually tested on small, replicated plots to develop a wide range of information on performance and phytotoxicity. Small plots are used to insure thorough and uniform coverage of the plants, and to minimize the crop contaminated with experimental materials. Crops treated with materials in this stage of development must normally be destroyed, following completion of the tests.

Crop and Location of Tests:--Plants should be a uniform size and vigor, and plant size and planting distance should allow separation into units which may be treated separately. Varieties chosen should be typical of those common to the area. Pest density and stage of development should be relatively uniform throughout the test site. Preferably the pest population should be increasing at the time of treatment.

Plot Size and Design:--These will vary somewhat with the individual pests, but a minimum of 3 replicates per treatment should be used where uniformity occurs. The number of replicates should be increased where plant age, variety, rootstock, plant vigor or pest populations vary. The use of randomized blocks, latin squares or split blocks is desirable for later analysis of results. In some situations it may be desirable to use buffer plots around the test plots to minimize drift from treatment of adjacent plots.

Applications and Equipment:--Apply at recommended periods for best control of the pest or pest complex. The experimental materials should be applied alone initially rather than in combination with other ingredients such as fungicides so that their independent effects may be evaluated. Apply test materials with equipment and methods generally known to give adequate and uniform coverage approximating that in field use, and appropriate to the pest and crop involved. Apply the test materials in one or more of the commercial type of formulations, such as wettable powder, emulsifiable concentrate, ULV, etc. The pH can affect the performance of a pesticide and should be given due consideration.

The selection of a dosage will depend on available data but it is preferable to apply materials at two or more dosages approximating minimum and maximum rates. Where practical, both a standard treatment (one which has a background of information on its performance) and an untreated check plot should be included for comparison with experimental materials.

The number of trials with each candidate pesticide will vary considerably, but an adequate number of trials should be conducted to permit accumulation of data on: (1) Timing and dosage for best control; (2) Performance on various pest densities and stages; (3) Phytotoxicity to various cultivars at different growth stages; (4) Effects on non-target species; and, (5) Effects of weather on performance.

Equipment should be thoroughly cleaned before and after each use. Between each treatment, the entire spray system should be operated with water (or a compatible substitute) until only clear water is sprayed. If two or more rates of the same formulation of the same pesticide are used, begin the application with the lowest rate in order to minimize contamination.

Sampling:--Sampling methods, counting methods, methods of presenting results including yields and, in certain cases, plot size and design will differ with specific pests or pest groups and will be discussed under the individual pest or pest group.

Analysis and Reporting of Data:--If a question of relative effectiveness of treatments occurs, an analysis of variance and multiple range test or other appropriate statistical analysis should be conducted to determine the statistical reliability of the differences between treatments. If treatment means alone are provided, they should be accompanied by the standard deviation.

The following information should be included when reporting test results:

Name and address of investigator.
Product name and formulation used, indicating active ingredient.
Crop (variety) treated.
Location of the test [soil type (if applicable) and soil moisture].
Type irrigation used (furrow or sprinkler).
Plot size.
Number of replications.
Rate of application - a.i. per hectare.
Finished spray volume per hectare.
Method of application (type of equipment, type of spray, coverage).
Stage of crop growth.
Treatment dates.
Harvest date.
How samples were taken.
Number of samples taken.
Percent infestation.
Percent control.
Phytotoxicity (type and degree of).
Comments regarding unusual test conditions or performance.

Temperature and general weather conditions at time of treatment.

Rainfall or any unusual weather after the treatment.

Include comment on performance as related to commercial acceptability (including effects on yield).

Statistical analysis.

References:--Pertinent references are cited.

Large Scale Field Tests

By the time a pesticide receives a temporary or experimental tolerance or an exemption from a tolerance, several small scale field tests have been conducted and a considerable amount of data has been collected on efficacy, phytotoxicity and effects on non-target organisms. It is then desirable to observe its performance under typical commercial conditions.

Crop and Location of Tests:--Several field plots should be selected which are representative of varieties, ages of plants, cultural practices and pest populations which are commonly encountered throughout the area.

Plot Size and Design:--Plots suitable in size for commercial application should be used. These should have dimensions large enough to avoid drift problems.

Application and Equipment:--Compounds reaching this stage of development should be tested under a range of application techniques. This should include dilute and concentrate air-carrier applications, and aerial application if this method is to be used commercially. The test material may be combined with other commonly used agricultural chemicals to substantiate any previous compatibility information.

The formulation and dosage used should be consistent with probable commercial use in the area. The experimental pesticide should be compared with a standard treatment applied to an adjacent area of the planting. Where possible, comparison with a small, untreated check plot is desirable.

The number of trials will vary somewhat with the pest and how readily infestations may be found; however, 3 to 5 large-scale trials are usually adequate.

Equipment should be thoroughly cleaned before and after each use. Between each treatment, the entire spray system should be operated with water (or a compatible substitute) until only clear water is sprayed. If two or more rates of the same formulation of the same pesticide are used, begin the application with the lowest rate in order to minimize contamination.

Sampling:--Sampling methods, counting methods and methods of presenting results, including yields, will differ with specific pests or pest groups and will be presented under each pest or pest group.

Analysis and Reporting of Data:--Analysis of the results of large-scale field trials may not be practical because of the lack of true replication.

See small scale field tests for reporting of data.

References:--Pertinent references are cited.

FIELD CROPS

CORN, *Zea mays* L.

The following general parameters are applicable to the testing of insecticides for efficacy on corn, *Zea mays* L. Following this section, there are additional suggested guidelines for evaluating foliar insecticides for the control of specific insect pests of corn.

Crop and Location of Tests:--The corn variety selected must be agronomically adapted for the specific growing conditions experienced in the geographical location of the test site. The corn variety should be susceptible to feeding by the test organism (e.g., insect, mite).

The field, or test site within the field, should have uniform growing conditions (e.g., soil type and available moisture). A single corn variety should be utilized throughout the test plot. If large-scale plots preclude a single variety for the entire test site, a single variety must be utilized within each block of the experimental design. Uniformity of corn varieties is necessary to avoid masking of treatment effects through significant variety X invertebrate preference interactions.

Natural or artifical infestations of the test invertebrate may be used depending upon the specific conditions of the experiment. Extreme care must be exercised to ensure that laboratory reared invertebrate pests retain their preference for the host plant rather than prefer an artifical diet. The entire test site should be protected from pesticide drift originating from commercial applications of pesticides on adjoining fields.

The minimum plot size for small-plot ground equipment or high clearance sprayers is 3-4 rows x 15m (ca. 50 ft.). When using minimum plot size, data must be collected only from the center row(s) in order to minimize the effect of pesticide drift from adjoining plots. Because of the danger of drift in small plots, surface winds must be monitored closely and spraying must cease when pesticide drift is likely to mask treatment effects. When pesticide drift is unavoidable, plot width and length must be sufficiently large enough to eliminate drift into that portion of each replication (block) from which data will be collected.

Minimum plot size for aerially applied pesticides is 3 swath widths x 300 m (ca. 1000 ft.). Data should be collected only from the center 2 rows of the middle swath in order to minimize drift effect from adjoining plots. The two remaining swaths will serve as buffer zones. Surface winds often cause aerially applied pesticides to drift great distances. When using minimum plot size, spraying should cease when surface winds cause the pesticides to drift past the two buffer zones and into the middle swath. When drift is unavoidable, plot size must be increased to a size large enough to eliminate drift into that portion of each swath from which data will be collected.

Experimental Design:--A randomized complete block is the most widely used experimental design for evaluating pesticides against foliar arthropod pests of corn.

A minimum of three replications of treatments should be employed for either ground or aerially applied pesticides at a single location. When the same experiment is conducted at two or more locations, two replications of treatments at each location will yield valid experimental results if the data are analyzed in a combined analysis of variance. Three or more replications are needed, however, if single locations are to be analyzed individually. Generally it is desirable to test at several locations (environments) and to utilize different corn varieties in order to detect treatment x environment interactions, treatment x variety interactions, and treatment x variety x environment interactions.

Untreated controls and the recognized standard insecticide treatment(s) should be included in each replication (block) of the experimental design to provide bases of comparison. When it is impossible to have untreated controls because of the large acreage involved, it should be sufficient to compare the treatments with one or more acceptable standards.

Application and Equipment:--Equipment should be thoroughly cleaned before and after each use. Between each treatment, the entire spray system should be operated with water (or a compatible substitute) until only clear water is sprayed. If two or more rates of the same formulation of the same pesticide are used, begin the application with the lowest rate in order to minimize contamination.

Many of the organic phosphate insecticides breakdown rapidly in alkaline water (pH above 7.0). A testing kit can be used to determine the pH of the water supply and, in cities, this information is available from the water department.

At the initial testing stage, 2-3 rates should be applied. When an optimum rate has been established and testing is in the final stages of product development, then the optimum rate should be used.

The finished spray volume per hectare (acre) varies with crop growth stage and application method. 5-47 l/ha (ca. 0.5-5 gal/acre) usually are applied by air. Higher volumes can be applied by modification of the aircraft spray system.

95-568 l/ha (ca. 10-60 gallons/acre) are usually applied by ground equipment, such as small-plot sprayers and high-clearance sprayers. Higher volumes can be applied if necessary.

Analysis of Data:--Data should be subjected to analysis of variance and if significant differences are detected, multiple comparisons of treatment means should be conducted with a seperation test such as Duncan's Multiple Range or Tukey's Test.

Southwestern Corn Borer, *Diatraea grandiosella* (Dyar)

The stem of the corn plant is internally girdled by the 2nd generation larvae of this insect causing stem breakage and harvesting problems.

The stage of crop at application should be whenever the 2nd generation eggs are oviposited in sufficient quantities to warrant treatment, usually tassel and silk stages.

The stage of insect at application is the egg or early larval stage.

The intervals between application are 7 to 15 days, until oviposition ceases.

Sampling:--Dissect 10 plants from each treatment in each replication (block) for number of feeding tunnels of 2nd generation borers.

Examine plants from each treatment in each replication (block) for stalk girdling and record as percent girdling estimates.

Obtain yield samples at physiological plant maturity by manually harvesting at least 0.0004 ha (0.001 acre) from each treatment in each replication (block). If mechanical equipment is used, recheck each harvested plot for dropped ears due to insect feeding and record as percent of harvested ears.

Harvested ears should be examined individually for southwestern corn borer damage.

References

Arbuthnot, K.D., and R.R. Walton. 1954. Insecticides for control of the southwestern corn borer. *J. Econ. Entomol.* 47:707-708.

Keaster, A.J. 1972. Evaluation of insecticides for control of the southwestern corn borer in Southeastern Missouri 1967-1969. *J. Econ. Entomol.* 65:563-566.

European Corn Borer, *Ostrinia nubilalis*

Leaves are damaged by larvae feeding in the whorl; tunnelling is seen in the stalk; stalks break, ears fall due to feeding in the ear shank. Earlier generation larvae destroy food-conducting vessels with consequent weakening of the plant, reduction of ear size and weight, of number of grains and grain weight. Later generation larval cause loss of ears due to ear dropping and harvest efficiency is reduced.

The stage of the crop at application should be whenever eggs are oviposited in sufficient quantities to justify treatment. Artificial infestation of eggs should be timed so as to properly coincide with natural oviposition. Usually early whorl stage for first generation and tassel to silk stages for second generation.

The stage of insect at application is the egg or early larval stage.

Often only one application is made, a second application may be made 7-10 days following the first application.

Sampling:--Evaluation procedures for the leaf-feeding first-generation borer consist of a visual plant rating scale of 1-9 (1=little or no feeding damage and 9=highly damaged) for at least 10 randomly selected plants from each treatment per replication (block).

Stalk evaluations are made for the second generation borer and at least 10 plants from each treatment per replication (block) are dissected for number of feeding tunnels.

Yield samples are obtained at physiological plant maturity by manually harvesting at least 0.0004 ha (0.001 acre) from each treatment in each replication (block). If mechanical harvesting equipment is used, recheck each harvested plot for dropped ears due to borer feeding and record as percent of harvested ears.

Harvested ears should be examined individually for European corn borer damage.

References

Berry, E.C., J.E. Cambell, C.R. Edwards, J.A. Harding, W.G. Lovely, and G.M. McWhorter. 1972. Further field tests of chemicals for control of the European corn borer. *J. Econ. Entomol.* 65:1113-16.

Cox, H.C., and T.A. Brindley. 1958. Time of insecticide application in European corn borer control. *J. Econ. Entomol.* 51:133-7.

Harding, J.A., W.G. Lovely, and R.C. Dyar. 1968. Field tests of chemicals for control of the European corn borer. *J. Econ. Entomol.* 61:1427-30.

Corn Earworm, *Heliothis zea*

The principal damage is caused by larval feeding in the corn ears resulting in loss of kernels primarily at the distal end of the ear and secondary contamination of the ear by pathogenic organisms. The larvae also may occasionally feed as budworms in the whorl of the corn plant causing destruction of leaf tissue. Usually it is not economically feasible to treat field corn for corn earworm control.

If adult moths are present and ovipositing, the first application should be made at silking or 2-3 days prior to silking, or when 7-10% of the ears are silking.

The stage of insect at application is the egg or early larval stage.

Applications may range from as often as once every 24 hours to once every 3 days until the silks turn brown.

Sampling:--United States Standards for U.S. fancy grade fresh sweet corn permit no more than 10% damaged ears from all sources. The most common method of collecting corn earworm infestation data is to examine 10 or more individual ears from each treatment per replication (block) at harvest. Data are recorded as percent of injury-free ears, percent of worm-free ears, or percent of worm-infested ears.

References

Janes, M.J., and G.L. Greene. 1972. Corn earworm control on sweet corn ears in Central and South Florida, 1969-70. *J. Econ. Entomol.* 65:521-522.

Keaster, A.J. 1969. Corn earworm control on sweet corn in Southeastern Missouri. *J. Econ. Entomol.* 62:1513-14.

Fall Armyworm, *Spodoptera frugiperda*, Beet Armyworm, *S. exigua*, Corn Earworm, *Heliothis zea*

These insects feed in the whorl of the corn plant causing severe destruction of leaf tissue and occasionally migrate to the ears when the plants tassel. The principal budworm is the fall armyworm with beet armyworms and corn earworms sometimes present.

The stage of the crop at application is early whorl to tassel. The degree of control on whorl stage corn is not so important as for the ears.

The stage of insect at application is early to mid-larval stages.

Applications range from 2-22 with intervals ranging from 2-11 days apart.

Sampling:--Counts of at least 10 randomly selected corn plants are made in the center of each treatment per replication (block). The results are expressed as percent of injury-free or worm-infested plants. Observations are made from 1-7 days after the last insecticide application.

Reference

Greene, G.L., and M.J. Janes. 1970. Control of budworms on sweet corn in central and south Florida. *J. Econ. Entomol.* 63:579-582.

Western Corn Rootworm, *Diabrotica virgifera*, Northern Corn Rootworm, *D. longicornis*, Southern Corn Rootworm, *D. undecimpunctata howardi*

Adult corn rootworms feeding in large numbers (10+ beetles per ear) will eat corn silks and may prevent pollination. The adults will oviposit in the field, and if the field is planted to corn during the next growing season infestations of western and northern corn rootworm larvae are highly probable.

The stage of the crop at application is the silk stage when silks are visible and pollen is being shed.

The stage of insect at application is the adult.

Usually only one application is made. When silking intervals are prolonged or when rainfall may interfer with the first application, a second application may be necessary.

Sampling:--Adult counts of at least 10 randomly selected corn plants are made in the center of each treatment per replication (block). Counts are made prior to the first application, 24 hours following application, 72 hours following application, 1 week following application, and 2 weeks following application. Sticky traps may be placed in each treatment per replication (block) to augment or to replace the individual plant counts.

After the first insect-killing frost, 10 randomly selected soil cores are removed from each treatment per replication (block) - 5 samples are taken from within the rows and 5 from the interrow space. A single 1 pint composite sample is drawn from the thoroughly mixed whole sample originating from the 10 sub samples. The composite sample is then washed through custom-built rootworm egg extractors and the sample is counted for number of rootworm eggs. These eggs will hatch during the next growing season and the counts can be used to estimate insecticide effectiveness in reducing the infestation during the next growing season.

COTTON

Insect pests are generally present in cotton throughout the cotton producing areas of the United States in sufficient numbers to seriously effect yields of cotton unless control measures are applied. Insects of primary importance are the boll weevil, *Anthonomous grandis* Boheman; the bollworm, *Heliothis zea* (Boddie); and the tobacco budworm, *Heliothis virescens* (Fabricious). Other arthropods that are implicated as serious cotton pests include several species of thrips, the cotton aphid, *Aphis gossypii* Glover; the cotton fleahopper, *Psallus seriatus* (Rueter); spider mites, *Tetranychus* spp. These insects cause losses estimated in excess of $350 million to $400 million annually to cotton.

Boll Weevil

The boll weevil is the most important species of insect that attacks cotton in the United States and suggested evaluation procedures for this pest are emphasized. Many other insect pest species may be sampled and evaluated at the time data are being collected for this insect species.

Crop and Location of Tests:--Select a good agronomic variety of cotton. Select good uniform soil for the entire plot area.

Locate tests in four to five geographical areas of the boll weevil infested states.

Plot Size and Design:--

Ground Application-Plots must be large enough to prevent "spill-over," i.e., drift of applied materials to adjacent plots. Plots must be large enough that data collection will not interfere with normal development and maturity of the crop. For example, pulling squares from very small plots each week to monitor boll weevil infestations would delay maturity of the crop. Delayed maturity could compound the results of evaluation because late maturity could make the crop more susceptible to late season pests and weather.

The length of the plots also are important in terms of proper application of pesticides. Generally, when a spray machine first enters a plot, the speed of the machine and the boom pressure are slightly less than optimum. Thus, the rate of application may be higher than the intended rate. It is equally important also in terms of effective sampling procedures. One example is the potential effect of excessive square or fruit removal during sampling. In addition, plot size must be related to the behavior of the insect. For example, the boll weevil female tends to move down a row rather than across rows during her oviposition period. Thus, samples collected along a single row will "skew" the infestation data. Plots should be large enough to collect a random sample across and along several rows to obtain an accurate sample.

The minimum plot size should be 8 rows x 15.2 m (50 row feet); randomized block; four replications. Collect all data from the center 4 rows of these plots; do not collect data from plants within ca. 1.5 m (5 feet) of the ends of the plots. This provides 4 to 8 rows of buffer between data rows for the respective candidate compounds.

Aerial Application-For aerial application test plots the length of the rows are extremely important. Each plot should have at least 3 swath widths per plot (assuming swath width is at least 12.2 m (40 feet). Collect data from the center swath; at least three sub-samples may be taken from center swath. This will provide ca. 24.4 m (80 feet) of buffer data collection areas to prevent the influence of drift. Do not collect data within 45.7 m to 61 m (150 to 200 ft.) of the row ends because this area is usually not treated as thoroughly as the center of the plot.

Application and Equipment:--Standard high clearance on tractor mounted sprayer equipped with at least two nozzles per row mounted on the spray boom. One nozzle should be mounted directly over row. Calibrate ground sprayer to deliver 7.57 to 37.85 liters/ha (2 to 10 gallons of spray per acre). Calibrate aerial application to deliver 7.57 to 11.35 liters/ha (2 to 3 gallons of spray per acre).

Sampling:--Insect populations should be monitored at least weekly; counts should be made just prior to each insecticide application (no more than one day prior to application).

To monitor boll weevil populations, collect data by the square pulling method. To do so, collect no less than 25 green (do not collect yellow or flared squares) squares at random from each replicate. When squares become hard to find (in late August), take damaged boll counts, but this method is much less accurate because of multiple egg puncture.

Do not combine egg and feeding punctures. Count only egg punctures. Note egg punctures. Make notes on adult weevils as to general abundance of young weevils in white blooms, etc. Attempts to count adults on plants can be very misleading--it is directly proportional to the aggressiveness and thoroughness of the individual technician.

Record weekly damage counts and compute seasonal average infestations. All statistical analysis should be done on these seasonal averages. Report the weekly counts also so that the influence of unusually abundant rainfall, etc. can be studied. Yield data should be collected by mechanical harvester. At least 1/3 of the plot should be harvested for yield data. Care should be exercised in noting any excessive skips in the rows harvested. Any such skips should be measured. Often in test plantings, the frequent activity of insect sampling as well as inadequate planting procedures (for example, fungicides or effective systemics for early season pests may have been left out) may result in less than optimum stands. If skips are the result of phytotoxicity factors associated with the test material they would not be counted, but this is unlikely to result in skips (more likely to be consistent throughout the plot). Hand harvesting can be used, but this provides for greater variation in efficiency because of different people harvesting. Such variation can greatly influence yield data from small plots.

Analysis and Reporting of Data:--As mentioned above, data should be collected only from the center rows to allow a buffer between data rows of adjacent plots. Also, no data should be taken from the ends of rows. Analyze data by Duncan's new multiple range test and at the 5 percent level of probability.

The following data should be reported:

Name of Investigator:
Address of Investigator:
Crop: Varieties:
Soil Type (if applicable): Soil Moisture:
Experimental Design: Plot Size:
No. of Replicates:
Chemical Tested: Lot No.:
Formulation Tested:
Dosages Tested: Per 100 Gallons: Per Acre:
Method of Application:
- a. Type of Equipment:
- b. Type of Spray:
- c. Coverage:

Time of Application(s):
- a. Date(s):
- b. Stage of Crop:

Other Pesticides Applied:

Bollworm and Tobacco Budworm

The following test methodology to determine the efficacy of insecticides to control the bollworm and tobacco budworm on cotton is very similar to the method previously described under Boll Weevil - Cotton. Only the modifications of that method are noted below.

Application and Equipment:--Standard high clearance on tractor mounted sprayer equipped with at least two nozzles per row mounted on the spray boom. One nozzle should be mounted directly over row. Calibrate ground sprayer to deliver 7.57 to 30.28 liters/ha (2 to 8 gals. of spray per acre). Calibrate aerial application to deliver 7.57 to 11.35 liters/ha (2 to 3 gallons of spray per acre).

Sampling:--Insect populations should be monitored at least weekly; counts should be made just prior to each insecticide application (no more than one day prior to application).

For moniotring *Heliothis*, collect the following data: (1) egg count; (2) live larvae in terminals (upper 18 inches of main stem); (3) *Heliothis*--damaged squares; and (4) *Heliothis* damaged bolls.

Heliothis egg counts in small plot research can be misleading because moths are immobile in plots treated with the most effective material, and egg counts may be equal to or may surpass counts in the controlled plots. However, a record of egg counts will allow a more accurate determination of effectiveness of an ovicide--insecticide. For example, there may be 100 eggs per 100 terminals but the next week only two larvae may be found on those 100 terminals. This is an indication of the effectiveness of an insecticide with ovicide properties. Count eggs only in the terminal portion of the plants. Sample 25 randomly distributed plants per replicate (within the center of the plot rows).

When sampling for eggs monitor live larvae in the terminals. These larvae will be invariably small (first to third instar). These counts will indicate the effectiveness candidate compound against small larvae. Check a minimum of 25 terminals per replicate for these counts. Check for squares for bollworm feeding damage. Again, a minimum of 25 squares per replicate are checked. This can be done in conjunction with boll weevil sampling.

In mid to late season, monitor *Heliothis* damaged bolls. This can be done by examining all bolls in 3.04 m (10 successive row feet) in each replicate. Thus a total of 12.2 m (40 row feet) are checked for each material. Count the total number of bolls present and the number of damaged bolls and convert the data to a percentage damage level or convert the data to the number of bolls and number of damaged bolls per acre. Either method is useful; however, the latter method is best because boll load can be correlated with subsequent harvest yield data.

Whenever possible collect a representative sample of the *Heliothis* larvae infesting the plant. Bring them back to the laboratory and identify them to species. By doing so, the ratio of the two species can be determined on a periodic basis. This data is very useful in interpreting the efficacy of the data. However, the collector must be careful with the sampling technique. *Heliothis zea* are more susceptible to organophosphate insecticides. *Heliothis virescens* are more tolerant to organophosphate insecticides. Thus, it is suggested that these collections be made adjacent non treated control plots.

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Lygus, *Lygus* spp.

Seasonal applications can start and continue or cease based on numberical counts of the *Lygus* spp. population. Generally this is from late May through late August. The established methods are thorough but very time consuming. De Vac counts take a lot of hours to count and to identify the many different species of insects present in the samples.

Crop and Location of Tests:--The variety should be a commercial variety for the test area, e.g., Acala.

The test site should be well selected to ensure a uniform population which is more likely to occur when the test site is in close proximity to such crops as safflower and alfalfa. The cotton should be in good growing condition, established and maintained under good agriculture practice consistent with the commercial growing requirements of the crop. Soil type shoud be suitable for the growth of the crop and as uniform as is possible throughout the test site.

Plot Size and Design:--Use a randomized complete block design.

Use at least 4 replicates per treatment. More replicates are needed where the population is light. *Lygus* adults are quite mobile, thus plots must be large enough to reduce migration between the treatments and also from outside areas.

Ground application plots should be 24-32 rows wide. Air application plots should be 6-10 swaths (2 x 12 meters) (6 x 40 feet).

Application and Equipment:--Applications should be made on a scheduled basis, but only as indicated by population sampling. No buffer rows are used but sampling is to be made from only the center rows of each treatment replication. Always include an untreated control, if possible, when crop loss is not a factor. Otherwise, it should be compared to the accepted standard.

The application equipment on large plots should be of a commercial type and the liters per hectare dictated by the size of cotton which can range from 57-227 liters (15-60 gal.) per hectare with nozzle placement such as to provide complete coverage. Usually the pressure will range between 2-3 kgm/cm^2 (25-35 psi).

Sampling:--Evaluate population density by making 50 sweeps per one row in the center of each treatment. Sample on both ends and in the middle of the single row on experimental plots. Sweeps should be made twice weekly plus a sweep sample before and after each chemical treatment. Treat only when twice weekly net sampling indicates that treatment is due.

Treatments should be made in the "early square" stage when 6-8 *Lygus* adults and/or nymphs appear per 50 sweeps.

Treatments should be made in the "early bloom" stage when 10 *Lygus* adults and/or nymphs appear per 50 sweeps.

Treatments should be made in the "peak bloom" stage when 15-20 *Lygus* adults and/or nymphs appear per 50 sweeps.

All new insecticides should be thoroughly checked and evaluated for any positive or negative effects on yield and quality. In the advanced stage of evaluation the cotton should be collected, weighed and graded in accordance with the acceptable commercial methods.

Any type of and the degree of, phytotoxicity should be reported provided it can positively be attributed to the test foliar insecticides. Such responses as stunting, leaf burn and chlorosis are usually the factors to evaluate.

Analysis and Reporting of Data:--The data should be analyzed using analysis of variance at the 5% level and check mortality, if any, accounted for by using Abbott's formula.

The following information should be included in reporting test results:

Product name and formulation used, indicating active ingredient.
Crop (variety) treated.
Location of the test.
Type irrigation used (furrow or sprinkler).
Plot size.
Number of replications.
Rate of applications - a.i. per hectare.
Finished spray volume per hectare.
Method of application.
Stage of crop growth.
Treatment dates.
Harvest dates.
How samples were taken.
Number of samples taken.
Percent infestation.
Phytotoxicity.

Comments regarding unusual test conditions or performance.
Temperature and general weather conditions at time of treatment.
Rainfall or any unusual weather after the treatment.
Include comment on performance as related to commercial acceptability.
Statistical analysis.

Reference

Sagaser, J. N. July 19, 1975. Personal written communications. Velsicol Chemical Corporation, Commercial Development, 6197 Millbrook Avenue, Fresno, California. 209/431-1678.

Mites, *Tetranychus* spp.

There are several different species of the *Tetranychus* genus that are a major problem in cotton. The conditions under which they exist or become a problem varies somewhat from region to region, but usually it is associated with weak cotton and under hot, humid, dry climatic conditions.

Crop and Location of Tests:--The cotton variety should be one that is grown in the test area for commercial purposes. Preferrably choose a variety, if there is more than one grown in the area, that is known to be highly susceptible to mites.

Soil suitable for cotton should be selected and preferrably an area where cotton has been grown previously. The soil type should be uniform and prepared consistent with good agriculture practice for the crop and area. There are specific activities that can be carried out in each region to encourage good mite populations and consultation should be pursued with the local Experiment Station and Extension authorities.

Plot Size and Design:--Use a randomized complete block design so that the results can be analyzed, statistically.

Use at least 4 replications per treatment and for ground application, each plot should be at least 16-24 beds wide (large replicates).

Use large replicates for air application, but replicates width's can be 3-4 swaths wide (36-48 meters) (120-160 feet).

With the replicates as large as have been suggested, buffer rows should not be necessary.

Sampling:--The fact that, under ideal conditions, mites reproduce rapidly and populations can reach epidemic levels in a short period of time requires that observations be made every 2-4 days.

For ground applications collect 25-50 leaves at random through the center of each plot and from various levels on the plant, i.e. bottom, middle, top. The leaves should then be brushed using a McBurnie mite brushing machine. Mites should then be counted, including all stages; egg, larvae and adult. In the case of larvae and adults, living and dead should also be recorded. The data can be presented as average living or dead and number of eggs per leaf.

Economically important levels can occur very rapidly under ideal conditions. Four-five (4-5) mites per leaf is approaching a critical infestation while 10-12 mites per leaf is critical and requires application.

Sample once weekly starting in June or July, and sample before and after each application. One or two (1-2) mites per leaf after application represents good control.

Yields are very ambiguous unless they can be directly related to the test foliar miticide. Yield data is very valuable, but it must be known that it is a direct result of the miticide or it is worthless information.

Any type of and the degree of, phytotoxicity should be reported, provided it can positively be attributed to the test foliar miticides. Such responses as stunting, leaf burn and chlorosis are usually the factors reported.

Analysis and Reporting of Data:--See Lygus - Cotton.

Reference

Sagaser, J. N. July 19, 1975. Personal written communications. Velsicol Chemical Corporation, Commercial Development, 6197 Millbrook, Avenue, Fresno, California. 209/431-1678.

Pink Bollworm, *Pectinophora gossypiella*

The testing and plot design of tests for *Pectinophora gossypiella* control are developed around the nature of the insect pest. The adult pink bollworm moth deposits the eggs under the calyx of the maturing cotton boll. The egg and hatching larva are protected here from chemical sprays. Except for a very short period of a few minutes to a couple of hours - between the hatching of the pink bollworm egg under the boll calyx and until the larva bores into the inside of the boll - the larva is not out in the open and susceptible to chemical applications. Chemical applications and research testing for larval control during this short "exposed period" of the pink bollworm are mostly unsuccessful or only partly successful. The best method for pink bollworm control is to control the adult moth. Thus, research programs are most successfully completed by monitoring and treating for adult moths.

The population density of the pink bollworm adult is most easily and accurately monitored by using pheromone traps, using daily moth counts to determine: a) if the pink bollworm is present in the test area; b) if the population density is increasing or decreasing; and c) the effects of various chemical or biological treatments on the adult moth.

Tests for pink bollworm control should begin sometime in July, in California and Arizona, in order to synchronize with the period called "peak boll set". This period is generally the time when the greatest number of vulnerable bolls are present, greatest crop injury can occur, and when the greatest population of adult moths is present. Test treatments showing greatest effectiveness during this period also automatically have demonstrated that the treatment will be effective on lesser population densities.

Crop and Location of Tests:--A cotton variety should be selected that is common to the test area and that is known to be susceptible to the pink bollworm. The variety should be recorded in the test data forms.

Site selection and the time to make the first application are difficult to determine. Pink bollworm pheromone traps are excellent and accurate, but are often not readily available or it is expensive to acquire the traps and pheromone. Boll cutting will give larval counts and establish that pink bollworm is present, yet does not indicate if the adult moths are present during the test. Larval counts prove only that adults were present earlier to deposit the eggs.

Plot Size and Design:--Use 4 replications per treatment and a randomized complete block design.

For ground applications, plots should be one-tenth of a hectare or larger. Ground applications should have plots separated by a minimum of 2 buffer rows.

Aerial application plots should be a minimum of 3-5 swaths wide (36-60 m) (120-200 ft.). Be certain that all sampling of traps and bolls is from the center of each plot.

Application and Equipment:--Two methods may be used for evaluating treatment effectiveness on pink bollworm adults: a) "one or two application" testing; or b) "seasonal application" testing.

"One or two application" testing is sometimes the less accurate of the two methods. The primary reason is that the test is often completed missing the peak adult moth density, and/or the control treatments are not held under pressure over a long enough period to be certain that control would be maintained.

This test is often necessary a) when testing time is limited; b) in early screening trials; and/or c) when sufficient chemical materials are not available for seasonal use.

The best way to make the test results most accurate with the "one or two application" method, is to use pheromone traps prior to the peak boll period. The first adult moth to appear is a fairly accurate estimation of when to apply the first treatment. If two applications are desired, the second application is applied one week following the first application.

The pheromone trap counts early in the season - just before application, and following application - will measure the effectiveness of each treatment. Weekly boll cutting of 100 bolls before, during and after application will indicate each treatment's effectiveness also.

"Seasonal application" testing for pink bollworm is aimed at controlling the adult pink bollworm.

Pheromone traps should be placed in the field in adequate numbers and locations to thoroughly monitor the adult moths. Place the traps and make daily counts early in the season, before pink bollworms normally appear in the field (prior to peak boll set). Peak boll set is a 5-7 week period, usually starting in July, when most boll damage and infestation occurs and when the most vulnerable bolls are present. Application generally starts just prior and during peak boll set. This usually coincides with the population count increases in the pheromone traps and infestations in the bolls.

Boll counts should be made after adult moths appear before and after each treatment is applied. Boll counts are to be used to monitor populations and the presence of infestations, not to determine when to apply the treatments.

Treatment applications - Apply the treatments weekly for 5-7 weeks, based on population pressure of pink bollworm adults as determined by the trap counts. Make daily pheromone trap counts of adults and weekly boll counts throughout the entire testing season or period.

Sampling:--There are two methods of evaluation of pink bollworm populations:

1) Pheromone traps and daily adult moth counts from the traps. Pheromone traps are best for monitoring the adult moth population to determine: a) when the adult moths' presence starts and ends; b) when peak treatment is needed; and c) the effect of the test treatments on the adult population.

2) Cutting of 100 bolls weekly. Weekly boll cutting of 100 bolls collected at random from each treatment indicates if indeed pink bollworm is present in the test area.

Although delayed, boll cutting tends to give an indication of treatment effectiveness. Boll cutting for larval counts is not a good indicator of when to start treatments. Larval presence does not mean continued adult moth presence. As stated earlier, because the larvae are inside of the bolls, larval treatment is futile. Adult moth kill is the only effective population control of pink bollworm.

Cotton boll selection - At random, collect 100 of only the firm shiny green bolls, approximately equal to a quarter or a fifty cent piece in size. These bolls are generally between 12 and 24 days old. Older or younger bolls are not used for counts becuase younger bolls are not mature enough for the larvae, and older, tougher hulled bolls cannot be penetrated by the young larvae just hatched from the egg. Cut each boll and inspect each section of the boll for larvae damage.

Always sample bolls at random and from the center of each plot away from the plot margins.

Always include a standard and an untreated check for comparison with the other treatments.

Analysis and Reporting of Data:--See *Lygus* - Cotton.

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SORGHUM, *Sorghum bicolor* L. (Moench)

The following suggested methodology for evaluating pesticides for the control of foliar invertebrate pests of sorghum is identical in general parameters to the testing of insecticides for efficacy on corn as described previously in this volume. The differences occur in the sampling procedures following the specific pest. See Field Crops - Corn for general parameters.

Greenbug, *Schizaphis graminum* (Rondani)

The insect feeds on the leaves and stem. While feeding it injects toxic saliva which destroys plant tissues. Early symptoms are red patches on some lower leaves and partly or completely necrotic leaves. Moderate greenbug attack causes stunting and delayed maturity as well as lowered yields. Severly infested plants may be killed by greenbug feeding.

The stage of the crop at application depends upon insect infestation, from emergence to pre-boot and later.

The stage of insect at application is all life stages whenever population densities of beneficial insects are insufficient to prevent greenbug outbreaks.

The interval between application varies from 1-3 applications, 3-7 days apart.

Sampling:--Pretreatment greenbug counts from at least 10 randomly selected sorghum plants from each treatment per replication (block) should be made.

Two or more post-treatment greenbug counts from at least 10 randomly selected sorghum plants from each treatment per replication (block) should be made. Sampling intervals vary from 4 to 15 days. A common sampling scheme is to make counts at 3, 7, 14, and 21 days after application.

As an alternative to whole plant counts, greenbugs may be counted on 1 leaf from each of 10 randomly selected sorghum leaves per replication (block). The same numbered leaf (counting from soil level) should be examined on a given sampling date.

The number and location leaves killed by greenbugs may be recorded in each plot 1-2 weeks following peak greenbug infestation.

Yields may be obtained by manually harvesting at least 0.0004 ha (0.001 acre) from each treatment in each replication (block). Manually harvested sorghum heads may be threshed, and the seeds cleaned, weighed, and converted to kg/ha (lbs/acre) at 12.5% moisture. Mechanical harvesters also may be employed.

The effect of the test insecticides on non-target insects, i.e. beneficial insects, should be recorded for each insecticide.

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Sorghum Midge, *Contarinia sorghicola* (Coquillett)

The sorghum midge larvae feed on developing ovaries and grain fails to mature. Affected spikelets remain tightly closed and, in severe infestations, whole heads fail to set grain. On dissection, larvae and pupae may be seen in the spikelets.

The stage of crop at application is when 20% of sorghum heads begin to bloom.

The stage of insect at application is the adult.

The interval between applications is 3-7 days. Usually only 1-2 applications are made.

Sampling:--Adult midges present at midmorning 2-3 days after application can be counted on at least 10 sorghum heads for each treatment per replication (block) as a measure of immigration.

The number of midges emerging from 10-40 sorghum heads for each treatment per replication (block) is determined by excising heads and holding the heads in emergence cages.

Mature sorghum heads are collected and the levels of midge infestations are determined by examination based on midge damage to individual florets. At least 10 mature sorghum heads should be harvested from each treatment per replication (block).

Yields are likely to be the best method of evaluating insecticide efficacy against the sorghum midge. Yields may be obtained by machine or manual harvest of a least 0.0004 ha (0.001 acre) sub plots from each replication (block). Manually harvested sorghum heads may be threshed, and the seeds cleaned, weighed, and converted to kg/ha (lbs/acre) at 12.5% moisture.

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Banks Grass Mite, *Oligonychus pratensis* (Banks)

Mite damage to the sorghum plant is expressed as discoloration, drying, and/or premature death of the leaves. An additional problem is the death and subsequent lodging of mite-infested plants. Additionally, the mites may so weaken the plant that disease organisms partially overcome the natural resistance of many plants. The symptomatology is: (1) small, white stipuled spots occur on the leaf along the midribs; (2) the spots increase in size, especially on the basal 1/2 of the leaf, followed by red or brown discoloration of the spots; (3) leaves fold downward along the midrib, especially on the basal 1/2 of the leaf, and death of all or a portion of the leaf follows; (4) symptoms proceed from leaf to leaf up the plant, and some leaves may be unaffected. Damage to heads consists of shriveled seeds and extensive webbing.

The stage of the crop at application is the late-mild to early-soft-dough stage and later stages of plant growth.

The stage of mite at application is all life stages.

Usually only 1 application is made. Under situations of severe stress a second application ca. 10 days following the first application may be warranted.

Sampling:--Pre- and post-treatment counts are made by visual selection of 10 of the most heavily infested leaves from each treatment per replication (block). A single microscopic field of 0.5 -in. diam. is selected in the most densely infested area on the leaf. All life stages (eggs, larvae, early and late-stage nymphs, and adults) of mites in each microscopic field are counted.

An alternative to counting mites while the mites are on the leaves is to select the 10 most heavily infested leaves from each treatment as described above. Then, a strip of cellophane tape is placed across the most-dense colony on the underside of the selected leaf. The tape is then placed on a 1" X 2" glass microscope slide. The slide is then inverted and the number of mites per unit area is determined by viewing a 0.5-inch diam. circle through a calibrated microscope field. (Personal communication, Dr. Jay D. Stone, Kansas State University).

Observations are made on plant lodging by counting lodged plants on at least 0.0004 ha (0.001 acre) from each treatment in each replication (block).

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Ward, C. R., E. W. Huddleston, J. C. Owens, T. M. Hills, L. G. Richardson, and D. Ashdown. 1972. Control of the Banks grass mite attacking grain sorghum and corn in West Texas. *J. Econ. Entomol.* 65:523-529.

SOYBEANS

Insect pests are sometimes present in soybeans throughout the soybean producing areas of the United States in sufficient numbers to seriously affect yields of soybeans unless control measures are applied. Soybeans are attacked by insects that feed on the seedlings, foliage and pods. Insects that attack the seedlings and stems include various species of cutworms, the three-cornered-alfalfa hopper and the lesser cornstalk borer. The principal forage feeding insects include the velvetbean caterpillar, *Anticarsia gemmatillis*; soybean looper, *Pseudoplusia includens*; cabbage looper, *Trichoplusia ni*; beet armyworm, *Spodoptera exigua*; the fall armyworm, *Spotoptera frugiperda*; the green cloverworm, *Plathypena scabra*; the bean leaf beetle, *Certoma trifurcata*; and the Mexican bean beetle, *Epilachna varivestis*.

Pod feeding insects include the "podworm," *Heliothis zea*; and stinkbugs, *Nezara veridula*; and *Acrosaternum hilare*. The podworm and stinkbugs are perhaps the most important insects that attack soybeans. The podworm is the "key" insect pest to soybeans in the south and southeast. This insect attacks beans from pod-set to pod-maturity. Infestations are usually heavier following treatment for foliage feeding insects prior to bloom. The podworm usually occurs in damaging levels from mid August to mid September. The small worm usually starts feeding on the leaves and blooms then bores through the pods and destroys several beans. Both the nymphs and adults of stinkbugs suck juices from young soybean pods causing discoloration to the beans and subsequent reduction in grade.

Podworm, Stinkbugs and Defoliating Insects

Crop and Location of Tests:--Select a good agronomic variety; select good uniform soil for the entire plot area.

Locate tests in 4 to 5 geographical areas of soybean production.

Plot Size and Design:--

Ground Application - Plots must be large enough to prevent spill-over, i.e., drifts of applied candidate compounds to adjacent plots. Plots should be 4 to 8 rows wide and at least 40 to 50 ft. long (border rows are desirable if the test area is large enough). The plot should be randomized and replicated at least four times. The rates of materials, i.e., active a.i. per acre, would be variable with the objective of the test. The finished spray and volume per acre is variable but generally within the range of 18.9 to 75.6 liters/ha (5 to 20 gals. of spray mix per acre).

Aerial Application - For aerial application test plots the length of the rows are important. Each plot should have at least three swath widths per plot assuming plot width is at least 12.2 m (40 feet). Collect data from the center swath; this will provide approximately 24.4 m (80 ft.) of buffer data collection areas to prevent the influence of drift. Do not collect data within 45.7 m (150 ft.) of the row ends because its area is not usually treated as well as the center plot.

Application and Equipment:--Standard high clearance on tractor mounted spray equipped with at least two nozzles per row mounted on a spray boom. One nozzle should be mounted over the row. A knap sack sprayer may also be used preferably with compressed CO_2 and pressure regulator ($2.1-4.2$ kg/cm^2 (30-60 psi)). The interval between treatment and observation should be from 24 to 48 hours. The interval between observation should be 5-7 days for the duration of the growing season. This is necessary to gain information on impact to non-target species and resurgence of pest species.

The timing of the application for certain insects is extremely important. For corn earworm (podworm), it is generally necessary to apply before plants develop a closed canopy. For the southern green stinkbug, economic infestations usually do not develop before pod-filling stage (4 to 8 weeks after first bloom). Crop growth stage should always be noted in materials and methods.

Sampling:--Apply materials as foliar sprays at rates postulated to give at least 80 percent control compared to untreated checks 48 hours posttreatment. Make insecticide counts on the two middle rows by shaking or beating the foliage over a ground cloth and recording live insects from the cloth. Sample at least six of these points within the center two rows of each plot. Three feet of row at each point is adequate. Record data on the number of live insects per 5.48 m (18-ft. of row). Calibrate percent control as follows: Percent control equals 100 x divided by the ck, whereas x equals the average number of live larvae 48 hours after insecticidal treatment and ck equals the average no. of live insects after 48 hours in untreated check. Eighty percent control is generally considered the minimum level of control. It is usually extremely difficult to get an accurate count of dead individuals on most species; consequently, counts of live insects remaining after 48 hours is important. The degree of plant injury and economic threshold levels in most bean producing areas is one per foot of row for corn earworms and stinkbugs. For all other defoliate feeders it is 33 percent leaf loss prior to bloom and pod-set and not to exceed 20 percent after pod-set until pod-maturity.

Yields should be taken especially if tests involve timing of applications according to economic thresholds. Harvest before beans become dry enough to shatter. Fifteen to 18 percent moisture is a good time to harvest.

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Mexican Bean Beetle, *Epilachna varivestis*, and Bean Leaf Beetle, *Cerotoma trifurcata*

The following procedure is adequate for field evaluation of foliar insecticides for the Mexican bean beetle, *Epilachna varivestis* (larvae and adults), and the bean leaf beetle, *Cerotoma trifurcata* (adults).

Crop and Location of Tests:--Choose a variety that is common to this crop on a commercial basis and for the area in which the field test evaluation is conducted.

The selected test site should be typical for the crop and selected so that drift of insecticide from neighboring crops is not a hazard or that interference from any other practice with adjacent areas will not interfere with the results in the test plot. The soil should be uniform and prepared in a manner acceptable to the normal method for that crop. Fertilizer and irrigation, if used and/or necessary, should be used in accordance with good agricultural practice for the crop. The test site should, if possible, be selected in an area where there has been a history of Mexican bean beetle and bean leaf beetle infestations.

Plot Size and Design:--Small plots for preliminary evaluations can be two rows in width and 15 m (50 ft.) in length. Each plot may be considered a single replicate and four replicates for each insecticide treatment are considered desirable. It is also suggested that an untreated buffer row be established between each plot to minimize the effects of drift. 1.5-1.8 m (5-6 ft.) alleyways are also recommended to separate the blocks. Such a plot setup should be on a randomized complete block design so that the data may be analyzed statistically for significance.

Large plots should be set up on the same basis with a randomized complete block design. The treatment replicates can be 4-6 rows wide and 30 m (100 ft.) or more long. In the larger plots it is not necessary to leave buffer zones or to separate blocks.

Air-applied plots should be a minimum of 36 m (50 ft.) wide (3, 12 m swaths) to prevent drift and to have enough area in the middle of the plots to select a random representative plant grouping to make the counts. The length of the plots should be such that the pilot can fly level and safely for at least 180 meters (600 ft.).

Application and Equipment:--Small plot applications can be applied with CO_2 spray equipment. Such equipment is, by design, compact, light and portable. This equipment is very adaptable and accurate; and since it is light, operator fatigue can be kept at a minimum. Nozzle selection should be made on the basis of complete coverage, and usually a fan-type nozzle is adequate when using 95-151 l (25-40 gals.), usually 132 l of spray solution per hectare at 3-3.5 kgm/cm^2 (25-30 psi). All evaluations, of course, should be done prior to applying the test materials. Sprayer should be well cleaned before each test and between the applications of different rates for each treatment. It is advisable to progress from low to high rate to minimize problems of contamination from one treatment to the next.

Large plot applications should follow the same basic outline; however, with much larger plots and with commercial-type spray equipment and all plots should be set up using a randomized complete block design.

The same plot setup should be used with air application, using 19-38 l (5-10 gals.) of total spray per hectare. Replication is important, but randomizing the plots is difficult with air application.

The number of applications will depend on the density of the insect population; usually a 7-10 day schedule is more than adequate, but should be dictated by the presence of pests in the test area and that relationship to the untreated controls.

Sampling:--The population level of the insects can be determined by taking five sweeps per plot with a 38 cm (15 in.) net or by spreading a 1 m (3 ft.) long drop cloth between the rows and dislodging the insects from the plants on both sides of the cloth by tapping the plants with a stick. The insect counts can then be recorded as the X number of insects, according to species per sweep or per 1.8 m (6 ft.) of row 1 m (3 ft.) on each side of drop cloth.

An estimation of insect feeding damage is also made for each plot on a scale of 0-100%. Each insect's feeding damage is unique and thus easily recognizable. *Cerotoma trifurcata* eat rounded holes in the foliage while *E. varivestis* skeletonize the leaves. It should be mentioned, however, that this technique of evaluation is limited to one application and not multiple sprays, since the feeding damage evaluation at the time of the first spray could not be distinguished from the feeding damage of the second and subsequent sprays.

See also Introduction - General Methods.

Reference

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Southern Green Stinkbug, *Nezara viridula* (L.)

The southern green stinkbug, *Nezara viridula*, readily feeds on developing soybean seed in many areas of the southeastern United States. The nature and extent of the damage depends upon the state of seed development at which feeding occurs. Prices paid for soybeans are discounted for stink but damage based on ½ of the actual percentage of stinkbug damaged seed. Germinated emergence and seedling survival are reduced significantly by all degrees of southern green stinkbug damage.

Crop and Location of Tests:--Test plants should be a variety common to commercial soybean production, such as "Bragg", and planted in accordance with the normal planting season for soybeans in the test area. The variety should be known to be reasonably susceptible to green stinkbug infestations. Other common varieties grown in the test area are acceptable.

The test site should be so selected to be void of any possible drift hazards from other fields where insecticides may be applied. The crop should be planted and maintained in accordance with good agriculture practice for that crop and for the region in which the test site is located. The lime and fertilizer should be applied in accordance with soil test recommendations.

Since stinkbug populations will be affected by existing climatic conditions, care must be taken to see that good records of climatic conditions are maintained and reported or referenced in all reports.

Application and Equipment:--Use a randomized complete block design. Use at least 6-8 replicates. In order to maintain a known population, artificial infestation into cages over soybean plants is recommended.

Small plots can be applied with back pack sprayers with a spray wand prepared so that the entire plant is sprayed, usually one nozzle over the top and one from each side. Use 57-95 l (15-25 gals.) per hectare at 2-2.1 kgm/cm^2 (24-30 psi).

For large plots use commercial spray equipment preferrably with drop nozzles to ensure complete coverage. Use 57-95 l (15-25 gals.) of spray mixture per hectare at 2-2.1 kgm/cm^2 (25-30 psi). Use .2 to .4 hectare (½-1 acre) plots.

For air application use at least 3 swath widths (1x12x36 m) (3x40x120 ft.) per plot at 19-38 l (5-10 gals.) per hectare. Plots should be at least .4 hectare (1 acre) in size so as physical drift will not occur from adjacent plots.

Sampling:--The value of the foliar sprays may be determined by placing cages 1.8 x 1.8 x 3.6 m (6 x 6 x 12 ft.) with 1.8 cm (3/4 in.) galvanized iron pipe frames over 2 rows, 3.6 m (12 ft.) long after the sprays have been applied and dried on the plants. The stinkbugs are then artificially infested by placing fourth instar in the cages using 15 bugs per row meter. It is not necessary to sex the insects. Counts should be made by counting the number of live insects on 3, 7 and 14 days. Before the cages are set over the rows, all insects should be removed from the area to be caged.

Data should be presented as percent mortality based on number living and dead. The fourth instar stinkbugs should be collected from an untreated field.

See also Introduction - General Methods.

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SUGAR BEETS

Beet Armyworm, *Spodoptera exigua*, and Fall Armyworm, *Spodoptera frugiperda*

This procedure is adaptable to both small and medium-sized plots for insecticide evaluation of the beet arymworm, *Spodoptera exigua*, and the fall armyworm, *Spodoptera frugiperda*, on sugar beets.

Crop and Location of Tests:--Choose a variety that is common to this crop on a commercial basis and for the area in which the field test evaluation is conducted.

The selected test site should be typical for the crop and selected so that drift of insecticide from neighboring crops is not a hazard or that interference from any other practice with adjacent areas will not interfere with the results in the test plot. The soil should be uniform and prepared in a manner acceptable to the normal method for that crop. Fertilizer and irrigation, if used and/or necessary, should be used in accordance with good agricultural practice for the crop. The test site should, if possible, be selected in an area where there has been a hisotry of beet armyworm infestation.

Plot Size and Design:--Small plots for preliminary evaluations can be two rows in width and 15 m (50 ft.) in length. Each plot may be considered a single replicate and four replicates for each insecticide treatment are considered desirable. It is also suggested that an untreated buffer row be established between each plot to minimize the effects of drift. 1.5-1.8 m (5-6 ft.) alleyways are also recommended to separate the blocks. Such a plot setup should be on a randomized complete block design so that the data may be analyzed statistically.

Large plots should be set up on the same basis with a randomized complete block design. The treatment replicates can be 4-6 rows wide and 30 m (100 ft.) or more long. In the larger plots it is not necessary to leave buffer zones or to separate blocks.

Air-applied plots should be a minimum of 36 m (100 ft.) wide (3, 12 m swaths) (40 ft.) to prevent drift and to have enough area in the middle of the plots to select a random representative plant grouping to make the counts. The length of the plots should be such that the pilot can fly level and safely for at least 180 m (600 ft.).

Application and Equipment:--Small plot applications may be applied with CO_2 spray equipment. Such equipment is, by design, compact, light and portable. This equipment is very adaptable and accurate, and since it is light, operator fatigue can be kept at a minimum. Nozzle selection should be made on the basis of complete coverage, and usually a fan-type nozzle is adequate when using 95-151 l (25-30 gals.), usually 132 l (30 gals.), of spray solution per hectare at 3-3.5 kgm/cm^2 (25-30 psi). All calculations should be done prior to applying the test materials. Sprayer should be well cleaned before each test and between the applications of different rates for each treatment. It is advisable to progress from low to high rate to minimize problems of contamination from one treatment to the next.

Large plot applications should follow the same basic outline; however, with the large plots and with commercial-type spray equipment and, all plots should be set up using a randomized complete block design.

The same plot setup should be used with air application, using 19-38 l (5-10 gals.) of total spray per hectare. Replication is important, but randomizing the plots is difficult with air application and is generally not considered necessary.

The number of applications will depend on the density of the insect population; usually a 7-10 day schedule is more than adequate, but should be dictated by the presence of pests in the test area and that relationship to the untreated controls.

Sampling:--Pre-treatment insect counts are necessary and it is suggested that the counts be made on a random basis by choosing 5-10 plants per row, closely examining for insect damage and recording the number of larvae present. Counts should be made on plants within the first or last 1.5 m (5 ft.) of each row.

Post-treatment insect counts on days 1, 7 and 14 after spray application should be made in the same manner as for the pre-treatment counts. Additional sprays can be applied to the plots if the insect pressure within them builds to high levels.

See also Introduction - General Methods.

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SUGAR CANE

Sugarcane borer, *Diatraea saccharalis*

This test method is intended for the field evaluation of the efficiency of insecticides for the control of sugarcane borer, *Diatraea saccharalis*. Granular insecticide formulations have been recommended for the past decade for the control of this pest. In the most recent years, interest has developed in the use of low volume and conventional sprays for this purpose. The development of systemic insecticides effective for control of Lepidopterous borers and recent advances in aerial application techniques that permit low volume application of several insecticides have made spray programs feasible.

Crop and Location of Tests:--A variety should be selected that is commercially grown in the area and that is maintained and planted under good agricultural practice known to be acceptable for the crop in the test area. Scientific name and variety of crop should be recorded.

The test site selected should have a previous history of sugarcane borer infestations. Soil type should be favorable and free of other pests or problems that may influence the results. The test site should be located so drift from neighboring crops and/or tests could not occur. The insect population should be uniform.

Plot Size and Design:--Small plots are 3 rows by 7 m (24 ft.). Treatments should be replicated 4 times. Treatments should occur in 2-3 week intervals. At harvest it is suggested that 20 stalks be examined and the number of joints bored recorded.

In large plots, it is suggested that 25 to 50 randomly selected stalks be examined for feeding in the leaf sheath and examined for borer larvae. Record the number of live and dead larvae in post-treatment counts. For pre-treatment counts, follow the same procedure and correct for check mortality using Abbott's formula.

Application and Equipment:--It is suggested that the plots be set up on a randomized complete block design with treatments replicated 4 times. More replications are required in areas where infestations are slight.

Untreated controls should be used to determine the sugarcane borer population and to provide a good comparison for the treatments. In addition, a recommended and accepted standard should be used to compare the acceptance of the experimental compounds on a commercial basis. If it is impossible to have an untreated control, then the latter should suffice provided there is an acceptable population of insects.

The equipment should be well maintained and cleaned well after each treatment. In the case of liquids, water should be run through the system until it is clear and the granular equipment should be dusted and preferably some non-toxicant granules run through the machine to avoid contamination of subsequent treatments. Always start with the lowest rate to the highest rate. Using this sequence will minimize the problem of contamination.

When applying sprays as a ground broadcast spray, fan-type nozzles properly spaced to the nozzle specifications on the boom will provide adequate and thorough coverage.

Select amount of finished spray per hectare that compares closely with commercial applications for air and ground applications consistent with the various types of formulations, i.e. liquid and granular.

Sampling:--Tests should be initiated just prior to or at the time larval feeding begins. Treatments are usually initiated when 5% of the sugarcane stalks are infested with early instar larvae of the second generation. Applications should be made on a 2-3 week interval schedule. When feasible and on the basis of the judgement of the individual investigator, more than one interval should be evaluated.

For the small plots at a normal harvest, record the number of bored joints. In the large plot tests, 25-50 randomly selected stalks should be examined for signs of feeding in the leaf sheath and for borer larvae, recording the number of live and dead larvae in post treatment counts.

See also Introduction - General Methods.

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SUNFLOWERS

Sunflower Moth, *Homoeosoma electellum*

Sunflowers are grown under a wide range of conditions in California, Minnesota, the Dakotas and Texas with an approximate acreage of 500,000-600,000; however, statistics show quite an acreage variation from year to year. The acreage has increased over the years and now represents a significant acreage of a high-cash crop. The sunflower moth, *Homoeosoma electellum*, is considered a major pest of sunflowers.

Crop and Location of Tests:--The test plants should be a commercial hybrid of the hybrid sunflower, *Helianthus annuus* L., and one that is commonly grown in the test area. If possible, select a variety that is known to be susceptible to the sunflower moth. Planting time is important; a little later planting will increase the insect population but usually decrease quality and yield. However, this does not apply to the Texas high plains.

The test site should be typical of the area in which the crop is grown commercially. Soil type should be uniform and prepared with a cultural method consistent with growing the crop commercially. For the test area the crop should be fertilized and irrigated if necessary, but maintained under good agricultural practice for the crop in the area the test is located. Attempts should be made to locate plots in close proximity to shelterbelts, grassed waterways, roadside ditches, etc., to maximize possible insect infestations. Because of the environment and insect behavior, a minimum of two locations for each study is suggested.

Climatic conditions will cause wide variation in the insect populations, and hence as many locations as possible should be used to provide reliable results.

Plot Size and Design:--The use of statistically designed test plots in sunflower pest evaluation, in the eyes of the authorities, is one of personal choice. Some use randomized complete block designs and some use simple plot techniques designed around the insect population with a given field.

At least four replications should be used per treatment and more replications may be necessary where the insect population is moderate to light.

Each replicate should have the same number of plants and be the same size and, in the case of sunflowers, for small plots at least, a minimum of 3 m (10 ft.) fallow buffer is maintained on all sides of each plot.

For small plots the initial year to two years of study: the plots will depend on insect population with plots in the area of six rows [100 cm (40 in.)/row] by 16.32 m (54.4 ft.) in length (1/10 of a hectare) (1/40 acre). Plots of this size are not too large and yet will be adequate if yield information is desired at this stage of insecticide evaluation.

Large plots: it is again up to the individual researcher, but usually plots of this nature will run from 0.4-4 ha (1-10 acres) in size. In these plots it is recommended that buffer areas of at least 7.5 m (25 ft.) be used.

For aerially sprayed plots a minimum of five acres is used and two-three replicates are suggested. Because of the size of the plot, untreated checks are not recommended and the use of a recommended standard foliar insecticide is considered adequate.

Application and Equipment:--Most of the work has been done with six-row sprayers [100 cm (40 in.)/row] over the top. The procedure and equipment to use should approximate commercial equipment, and the amount of spray solution and pressure used should be consistent with that used commercially. Small plots are at the discretion of the researcher himself, and small equipment well proven as research equipment will suffice. The research should, when using different rates, progress from low rates to high rates to minimize contamination when moving from one rate to another. Sprayers should be thoroughly cleaned after application of each treatment. Take safety precautions.

Sampling:--Methods used for making control evaluations vary tremendously from one researcher to the next. There should be 2, 3 or 4 applications usually, and after the last application a minimum of 100 heads should be cut and taken to the laboratory for evaluation for insect numbers and damage. Applications should begin when 20% of the heads are in the flower stage. Some researchers use the DeVac machine, and when it is used, results should be presented as for other methods. However, its value in sunflower moth evaluations has not been established.

See also Introduction - General Methods.

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TOBACCO

Tobacco Budworm, *Heliothis virescens*, Tobacco Hornworm, *Manduca sexta*, and Cabbage Looper, *Trichoplusia ni*

Tobacco is a fairly localized restricted acreage luxury crop which is very susceptible to attack by several phytophagous insects, the most important of which include Lepidopterous, Coleopterous and Homopterous species.

It is important to determine the levels of pest populations in commercial fields and, wherever possible, include a comparison with a standard product.

Although this protocol deals with evaluation methods, it nevertheless should be pointed out that smoke flavor tests and resulting residues in green and cured tobacco should be considered very early in the evaluation program.

Crop and Location of Tests:--The tests should be set up on a variety that is grown commercially in the area and, preferrably, tests should be set up to cover different varieties, since each one can react differently to insecticides. If different varieties are used, however, each variety should be checked individually and as a separate test. The crop in the selected test site should be planted, grown and maintained in accordance with the accepted practice for the crop.

Soil that is typical, uniform and suitable for the growth of tobacco should be selected. The test site should be so selected that it is relatively free of drift from pesticide treatments of neighboring crops.

Climatic conditions are very important, and optimum conditions such as rainfall, temperature and soil moisture are all conducive to high insect populations when good to ideal. Tobacco is very susceptible to climatic conditions, and adverse conditions can produce plant symptoms which are often confused with insect damage such as stinkbugs, which are commonly called dry weather sun scald.

Application and Equipment:--Use a randomized complete block design. Use at least 4 replications per treatment. More replications will be needed if the insect infestation is light. Each plot should be 2 rows wide by 9.6-12 m long for small plots and preliminary evaluation, and twice that size for more advanced evaluations.

In the case of budworms, it is usually necessary to make at least two or more applications at weekly intervals until flower buds appear. Treatments should begin when budworms of any size are found on 5 or more plants out of 50 any time prior to flowering.

Hornworms are easily controlled and treatments are justified when 5 or more hornworms 2.5 cm (1 in.) or longer are found per 50 plants.

The cabbage looper, which is becoming increasingly more important as a tobacco pest, can occur throughout the development of the tobacco plant since there is more than one generation per season. Damage is to the leaves as opposed to the bud for the hornworms and budworms. The larvae is the only damaging stage and eats ragged holes in the leaves.

Equipment should be cleaned well before each application and treatments should be made so that the rates progress from the lowest to the highest concentration. Use one full cone nozzle 30-45 cm (12-18 in.) over the top of each row and apply a minimum of pressure, i.e. 1-1.4 kgm/cm^2 (15-20 psi).

Sampling:--All plants should be checked in both the treated and check plots and there should be at least one larva per plant to consider that plant infested. Record infested plants and, on post treated counts, new damage to leaf surface areas should be checked. Post treatment counts in shade tobacco should be made every 7 days, and on flue cured tobacco every 14 days.

A high degree of control is necessary, since the insect damage will significantly reduce the value of the crop. Control should be at least 90%, although in many cases a lower percentage is often accepted by the grower, but he is usually "docked" significantly in the purchase price.

See also Introduction - General Methods.

Green Peach Aphid, *Myzus persicae*, and Tobacco Flea Beetle, *Epitrix hirtipennis*

The green peach aphid, *Myzus persicae*, is usually a problem throughout the growing season, but will decrease as the plants become more mature and weather conditions are not optimum for its development late in the season.

Application and Equipment:--All insecticides should be thoroughly applied beginning in the early stages of the crop, and test can be continued throughout the normal growing season. Use up to 57-95 l/ha, less for the small plants and the maximum amount as the plants approach maturity. Use 2-2.1 kgm/cm^2 (25-31 psi) when making application using a cone nozzle.

Sampling:--For the performance evaluation of the green peach aphid, actual insect counts per leaf can be made. The counts should be made 4 leaves down from the bud, selecting a leaf 7.5 cm (20 in.) long or longer. The right half of the dorsal upper surface between the fourth and fifth lateral veins should be used and all the aphids in that area should be counted.

Tobacco flea beetle, *Epitrix hirtipennis*, performance evaluation for early season should include an evaluation of the number of holes in leaves of the check plant and all the leaves on at least 10 plants, or examination of enough plants in the check plot to yield a total of 50 holes recorded. An equal number of plants in the treated plots should be examined and the number of holes counted and recorded.

See also Introduction - General Methods.

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WHEAT, *Triticum* spp.

The following suggested methodology for evaluating pesticides for the control of foliar invertebrate pests of wheat is identical in general parameters to the testing of insecticides for efficacy on corn as described previously in this volume. The differences occur in the sampling procedures following the specific pest. See Field Crops - Corn for general parameters.

Greenbug, *Schizaphis graminum* (Rondoni)

The aphids feed on the leaves and stem of the wheat plant and inject a toxic saliva which causes discoloration and tissue destruction. When conditions are favorable for greenbug outbreaks the infestation may spread rapidly and the entire field may be killed.

The stage of the crop at application depends upon insect infestation, from emergence through heading. The most common crop stage for greenbug attack is the tillering stage.

The stage of the insect at application is all life stages whenever population densities of beneficial insects are insufficient to prevent greenbug outbreaks.

The interval between application is 3-7 days and the number of applications varies from 1-3.

Sampling:--Pre-treatment and post-treatment greenbug counts are made by counting the total number of all stages of greenbugs present in 0.30 m (1 ft.) of linear drill row of wheat. At least 5-10 such counts are made for each treatment per replication (block) at randomly selected counting stations. Usually one pre-treatment count is made and 3-4 post-treatment counts are made on a schedule of ca. 1, 3, 7, 14 days. The number of important parasites and predators should be recorded at each counting station.

Yield data are collected by hand harvesting 0.0004 ha. (0.001 acre) areas within each treatment per replication (block). The heads are threshed and the grain weighed and converted to kg/ha (lbs/acre).

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WINTER WHEAT

Pale Western Cutworm, *Agrotis orthogonia*

The pale western cutworm, *Agrotis orthogonia*, is a serious pest of winter wheat throughout most of the Great Plains of the United States and prairie region of western Canada, particularly during years of dry weather.

Crop and Location of Tests:--The test plants should be a variety that is grown commercially in the test area and known to be susceptible to cutworms. Varieties such as "Lancer" or "Scout" may be used.

For best results select a dryland field where the soil type is uniform. The crop, winter wheat, should be planted consistent with a cultural method that is typical for the crop in the test area. It should be so selected that it is free of drift from pesticide treatments to neighboring crops.

Climatic conditions are very important, as dry spring weather favors cutworm survival; excessive moisture promotes bacterial and fungus diseases that attack the larvae and may give complete control. Excessive moisture also drives the larvae to the soil surface and exposes the cutworm larvae to parasites and predators.

Application and Equipment:--Use a randomized complete block design. Use at least four replicates approximately .01 ha (1/40 acre). Plots should be larger if populations are light. For large ground plots where compounds are in the advanced development stage plots of .4-.8 ha (1-2 acres) are acceptable. Air plots should be larger, each swath about 12 m (40 ft.) with at least 3 swaths per treatment.

For small plots, a portable boom backpack sprayer with pressure regulator and compressed air cylinder may be used in .01 ha (1/40 acre) plots. Use 2 kgm/cm^2 (30 psi) and 57 l per ha (15 gals/acre).

Sampling:--Population densities are determined at various post-treatment intervals by examining four 0.3 m^2 (1 ft.^{2}) samples of soil in each plot to a depth of 10 cm (4 in.). Soil from each samples is hand-sifted through a screen and larvae counted. Percent control is determined by population reduction versus the check.

At harvest, wheat samples may be obtained for yield data by hand-cutting four 2.5 m (8 ft.) rows randomly selected from the center of each plot. Samples can be processed through a stationary thresher, after which the seed is chained, weighed and yields converted to kg/ha (lb/acre). All data should be analyzed statistically by applying the F test and treatment means separated by applying Duncan's Multiple Range Test at the 5% level.

See also Introduction - General Methods.

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FORAGE CROPS

Forage crops and especially alfalfa support a wide variety of insects and these include species destructive to forage and other crops, pollinating insects, species that inhabit the forage because of the lush growth but have very little effect on the crop, and many predators and parasites of forages or other neighboring crops. It is suggested that the field evaluation of invertebrate control agents should take this variety of insect species into consideration. In many cases an evaluation test applied for one species will yield data on other pest and beneficial species if these are sampled and counted at the time data are being collected for the major species being evaluated.

Throughout the suggested practices, we will attempt to recommend minimums for small plot evaluations. Large scale tests with ground equipment should be applied on minimum 2.02 hectares (5 acre) plots.

Minimum plot size for air application should normally consist of at least three passes of the plane with samples taken in the middle swath. Spray volume is important in air application and reference is made to Wilson and Armbrust (1968).

In all cases, evaluations should be made under ideal application conditions and with equipment that is in good working order and properly calibrated to give good coverage of the forage. Sampling of certain life stages of some pests is difficult and time consuming. Care should be taken to conduct sampling within the central area of the plot with consideration for edge buffer zones within the plot. In all cases a replicated pretreatment sample should be taken within the test field. It is not necessary to sample each plot. With species that are widely distributed, it is generally felt that evaluations should be conducted in major use areas with 2-3 test sites per area.

Alfalfa Weevil and Egyptian Alfalfa Weevil

Because the alfalfa weevil, *Hypera postica* (Gyllenhal) and the Egyptian alfalfa weevil, *Hypera brunneipennis* (Boheman) are the most important single insect pest species of alfalfa in the United States, we will emphasize suggested methods for these two pests.

Crop Variety and Location of Tests:--The alfalfa variety should be one that is susceptible to damage from the particular insect pest species under test and should be a variety commonly grown in the geographic area of the test site. A pure stand of alfalfa would be desirable for testing but in many geographic areas alfalfa is commonly planted mixed with other forages such as clovers and grasses. In these cases or those where voluntary forages have invaded an originally pure stand, a plant composition sample of the stand should be taken and each forage type including weeds should be reported as a percentage. The test should be located in an area where the weevil has been economically important for at least one previous year.

Experimental Design:--A valid experimental design should be used and we suggest the randomized complete-block design with a minimum of three replications per treatment. Plot size will depend on which life stage is being controlled and for how long. For larval control many researchers have used a minimum plot size of 3.05 X 6.10 meters (10 X 20 ft.).

Because of adult movements within a field and into a field, data to determine initial adult control should only be collected up to 24 or 48 hrs after the application. Niemczyk and Flessel (1969) obtained satisfactory results with 0.04 hectare (1/10 acre) plots. To determine the effectiveness of adult control programs over an extended period of time, Wilson and Armbrust (1970) and Niemczyk and Flessel (1969, 1970) used entire fields or a plot size of several acres with the remainder of the field being treated with a recommended adulticide.

Application and Equipment:--Spray applications rather than granular applications appear to give better coverage of the chemical unless a low percentage granular formulation is used. Most researchers feel that a minimum of 7.57 decaliters per acre (20 gallons) of finished spray should be used on first-crop alfalfa at 13.8 Newton's per meter^2 (20 p.s.i.). For spraying regrowth after harvest, 3.79 decaliters per 0.4 hectare (10 gallons per acre) is usually sufficient.

Sampling:--Population densities of each stage of the weevil are very time consuming to obtain and usually not necessary for comparing one treatment with another on a relative basis.

For most relative larval sampling the standard 3.8-decimeter (15-inch) diameter sweep net is used. It is swung across the top of the alfalfa the way in which the pendulum of a clock swings. One sweep is equal to one pass of the net and the return is counted as the second sweep (Armbrust et al. 1969). The number of sweeps should be adjusted to the population levels so numbers of insects obtained are valid for statistical analysis. Results should be reported on the basis of mean number of insects collected per sweep.

Adult sampling is difficult because at certain times and under some conditions, it is difficult to obtain meaningful numbers. We suggest that the number of sweeps per plot be adjusted so that valid counts of adults are obtained.

Additional sampling methods, comparison of methods, and processing of samples are reported by Callahan et al. (1966), Cothran and Summers (1972), Pass and Van Meter (1966) and Stevens and Steinhauer (1973).

When researchers (Armbrust et al. 1969) are evaluating the performance of insecticide treatments applied as larval sprays, counts are usually made at pretreatment and at 3, 14, and 21 days after application. Where more precise performance data are needed, additional sampling at 7, 10, 12 and 16 days after application is suggested. An estimate of percent of the foliage missing at each sampling data is further suggested.

Alfalfa yields in small plots are sometimes difficult to obtain because of plant variation and density within a stand of alfalfa and because of the presence of weeds. Hintz (1974) and Koehler and Rosenthal (1975) have obtained satisfactory results and their methods are suggested. A high percentage of feed nutrients in alfalfa are contained in the leaves which weigh very little in comparison to the bulky stems which contain a large amount of fibrous material of low nutrient value. Thus alfalfa weight records alone can be very misleading as an indicator of market value. Chemical analysis for protein is a good indicator of feed value and should be combined with weight records to assess pest damage. Protein can be determined by the method given in the 10th edition, 1965 Official Methods of Analysis, page 16, 2.044.

Analysis and Reporting of Data:--Data means should be compared using a valid statistical test for significance such as Duncan's new multiple-range test or Tukey's w-procedure. Treatment performance should be compared with untreated forage and one or more standard labeled insecticides that are recommended for the particular geographic test location.

The following data should be reported:

Insect population counts recorded as number of insects per sweep.

Insecticide formulation used and amount of active toxicant per hectare.

Amount of spray per hectare and the type of equipment.

Plant height and percent of foliage missing at time of treatment and on each sampling date.

Phytotoxicity rating.

Temperature and general weather conditions at time of treatment.

Rain measurement within 48 hours following treatment.

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Weevil Parasites

Most weevil parasites are parasitic in the larval stage. Of these, *Bathyplectes curculionis* (Thomson) is more wide-spread than any others and occurs wherever *Hypera postica* is found. Many other parasite species have been listed by Brunson and Coles(1968).

Because peak parasite activity may not always occur at the time of insecticide applications for weevil control, separate tests may be necessary to determine effects on parasites. Field data are extremely difficult to obtain because of adult parasite movements between treated plots and from untreated areas. Spray applications should be applied during adult activity and net counts made at 24 and 48 hrs after application. Counts made after 48 hrs would reflect emergence of untreated adult parasites and movements of adults into the treated alfalfa from untreated areas or other plots.

Researchers are suggested to refer to Davis (1970) for further details of insecticide control of weevils with resulting effects on parasites. Care should be taken not to use percent parasitism differences between treatments as an indication that one insecticide over another is less detrimental to the parasite. These differences, besides reflecting initial parasite kill, may also result from different parasite-host ratios during the post-treatment period.

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Spittlebugs

Crop and Test Site:--Spittlebugs are commonly found on alfalfa, red clover and birdsfoot trefoil. Spittlebugs have been abundant in the Eastern and North Central States. These insects produce little masses of white froth around themselves and the stems of alfalfa, clover, and other plants from which they suck sap through their sharp beaks. The young bugs begin feeding very early in the growing season and cause surprising losses in yield (USDA 1952). Control of the nymphal stage is easier to evaluate than control of the adults. The latter move readily until egg laying takes place and evaluation of adult control would require large plots.

The plots for evaluation of control of the nymphs can be as small as 6.1 x 6.1 meters (20 x 20 feet). The randomized complete-block design with 4-6 replications per treatment is suggested.

Applications and Equipment:--Spray applications are usually made at the first sign of spittle. This will appear as a single, small teardrop. Applications are best made with a low pressure type sprayer with 3.79 to 7.57 decaliters (10 to 20 gallons) of spray per 0.4 hectare (acre).

Sampling:--Counts should be made before the new adults appear. We recommend counts at pretreatment and 3, 7, 16 days after application. Counts should reflect the number of spittlebugs/meter^2.

Analysis and Reporting of Data:--Same as for weevil except insect counts reported on a meter^2 or ft^2 basis.

Potato Leafhopper

Crop Variety and Location of Tests:--The potato leafhopper does much damage to alfalfa. It is a pale-green, soft-bodied, wedge-shaped winged insect only about one-eighth inch long when full-grown. It often becomes extremely abundant on these crops and sucks the sap out of the leaves, causing them to turn reddish yellow and die (USDA 1952).

Evaluate on alfalfa, red clover, ladino clover, or birdsfoot trefoil.

Experimental Design:--Adult hoppers move rapidly so sizeable plots are necessary. Some researchers have found that minimum size plots of 6.10 x 12.2 meters(20 x 40 feet) are adequate with 4-6 replications per treatment.

Application and Equipment:--Apply the spray when populations of nymphs reach 1-2 per 20 sweeps and use a low pressure type sprayer.

Sampling:--Count only nymphs from sweeps taken in plots.

Analysis and Reporting of Data:--Same as above.

Aphids

Use same test procedure as for potato leafhoppers.

European Chafer, White Grubs, Clover Root Borer and Sitona Species

Crop Variety and Test Site:--Evaluate insecticides for these soil insects on susceptible crops and varieties.

Experimental Design:--Because the immature stages move very little the plots can be relatively small (3.05 x 3.05 meters) (10 x 10 feet). Researchers have found that randomized complete blocks or Latin Square designs are adequate with 4 replications per treatment.

Application and Equipment:--Use low pressure type sprayer or granular applicators.

Sampling:--Usually 3-5 square foot samples taken per plot to depth of 1 foot in the fall are satisfactory for the European Chafer. Where white grubs are heavy in permanent pasture, they can be counted on a square foot or meter basis after pealing back the pod. For the clover root borer, 10 roots per treatment is usually a satisfactory sample. These should be washed, dissected for borers and the root injury scored on a scale of 1-4.

Analysis and Reporting of Data:--Same as above.

Seed Chalcids and Plant Bugs

Crop Variety and Test Site:--Same as above.

Experimental Design:--Small plots of 6.1 x 6.1 meters (20 x 20 feet) are satisfactory for seed chalcids but larger plots of 12.2 x 12.2 meters (40 x 40 feet) are needed for plant bugs.

Application and Equipment:--Same as above.

Sampling:--For seed chalcids, harvest seed pods at random from 3-5 sites per plot. Counts are made by splitting the pods to determine shriveled vs. plump seeds. Seeds should be held until chalcids emerge.

For plant bugs count only the nymphs sampled with a sweep net.

Analysis and Reporting of Data:--Same as above.

Reference

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RANGELAND

The low value of rangeland forage, the rough terrain, and the vast acreages involved usually necessitates aerial application of insecticides in almost all instances. Many of the species of insects which damage rangeland forage are quite mobile and this vagility, plus the variability in population densities and the necessity of evaluating aerial application, has led to the use of large (20 to 259 ha) plots for efficacy testing. Plot size often must be reduced in mountain or forest rangeland.

Careful attention should be given to the overall efficacy evaluation program to insure that the tests in different areas are a part of the same experimental design so that the number of replicates at a given site can be reduced. Sub-plots are often selected at random within the large plots to improve efficiency. Care should be given to selecting plot locations which will not involve spray applications over ponds or water courses unless it is the intention of the researcher to monitor for pesticides in those areas.

Insecticides in the development stage where crop destruction is required present a unique problem. In large pastures, electric fences and/or burning, where practical, may be required. Where possible, rapid determination of pesticide residue levels can be used to determine whether the crop can be utilized or if it must be destroyed.

Minimum plot size for aerial application will usually be three swaths wide by long enough to assume sustained level flight of the aircraft. Plots must be long enough to allow for variation in initiation of spray at each end. Plot size may be reduced by the use of smaller, slower aircraft. Width of plots or separation between plots must be adequate to prevent drift onto adjacent plots. Preliminary "screening" can be accomplished by low pressure-low volume sprayers. Minimum plot size is dictated by the mobility of the insect species involved. Border treatment with pesticides labeled for the particular use can be used to further reduce plot size.

Insecticides should be applied with carefully calibrated equipment under acceptable weather conditions. To make certain of this, more than one day may be required for aerial application of several treatments.

Grasshoppers

Crop Variety and Location of Tests:--Species composition of the vegetation and the terrain are usually dictated by the location of economic infestations of the pest. Care should be given to uniformity of vegetation and terrain among treatments. Proximity to watering sites will affect forage utilization and distribution of livestock.

Experimental Design:--At least two replicates, with several sub-plots per replicate should be the minimum. The use of only one plot per treatment may be acceptable when circumstances dictate and prior approval has been given by the Environmental Protection Agency. Whether or not untreated control plots are used, the incorporation of a recommended standard insecticide treatment is suggested.

Plots as small as 1.62 hectares (4 acres) or 35.3 x 457.7 meters (116 x 1502 ft.), separated from each other by similar size strips have been used for aerial application for grasshopper control in alfalfa, however, problems of migration of grasshoppers from untreated adjacent rangeland have been encountered (Jones and Kantack 1973). The same authors used 3.64 hectare (9 acre) plots which were 91.4 x 396.1 meters (300 x 1300 ft.) adjoining each other to reduce this effect. Skoog et al. (1965) used 16.2 hectare (40 acre) plots (¼ x ¼ mile) with the Piper Pawnee, 64.8 hectare (160 acre) plots (¼ mile x ½ mile) with a Stearman and 518.4 hectare (1280 acre) plots (2 x 1 mile) with a TBM. In another study, 32.4 hectare (80 acre) plots (½ x ¼ mile) were used with flight heights of 15.2 and 30.4 meters (50 and 100 ft.); 129.6 hectare (320 acre) plots (½ x 1 mile) were used with flight heights of 60.8 meters (200 ft.) (Skoog and Cowan 1968). Holmes et al. (1965), in Canada, used 1.2 hectare (3 acre) plots (100 x 145 yds) for ground application with a low pressure-low volume sprayer equipped with nozzles 50.8 cm (20 in.) apart on a 9.14 meter (30 ft.) boom with the sprayer calibrated to deliver 37.4 liters/hectare (4 gal./acre).

Application and Equipment:--Aerial application equipment designed and evaluated for the aircraft being used should be properly calibrated. Aircraft designation; boom size and length; number, size of nozzle, or atomizers and position on aircraft; pressure; aircraft speed; height and swath width; type of solvent; concentration of solution and quantity of solution used should be reported. Dye cards for evaluation of deposit uniformity are recommended. Flight runs made crosswind usually increase the uniformity of deposits. Applications should be made under conditions that avoid excessive convection currents.

Sampling:--Population densities of grasshoppers are usually evaluated with the visualized square foot technique with (Skoog et al. 1965) or without (Jones and Kantack 1973) teasing. Other workers have used the square yard as a sampling unit. The number of square feet sampled varies from 25 in 1.62 hectare (4 acre) plots to 100 in larger plots. Samples are taken along transects that divide the plot into thirds (Skoog et al. 1968) or through the center section and at diagonals to the line of flight (Jones and Kantack 1973). The edge effect produced by migration from untreated areas may be especially pronounced in grasshopper studies.

Sampling at approximately the same time of day and under similar weather conditions can be used to reduce variation (Jones and Kantack 1973).

Jones and Kantack (1973), citing Anderson (1961), state that areas sampled should be disturbed as little as possible to minimize changes in grasshopper distribution and activity.

Holmes et al. (1965) used a standard 3.8-decimeter (15 inch) sweep net with three sweepers each taking 30 sweeps in a 1.2 hectare (3 acre) plot.

Grasshopper counts should be taken immediately prior to the treatment three days and seven days after treatment. Additional information may be gained by sampling one or two days after treatment.

Analysis and Reporting of Data:--Where possible, treatment means should be compared using a valid statistical test for significance. The standard material used in private-state-federal control programs in the geographic area should be included. Replicated untreated plots are also recommended.

The following data should be reported:

Description of terrain, and dominant vegetation, including plant height, stage and condition at time of treatment.

Insecticide formulation used, kilograms active toxicant/hectare and liters/hectare of spray.

Describe equipment in detail (type of aircraft or application equipment, speed, height, swath width, type, number and arrangement of nozzles or other apparatus, etc.

Ground surface temperature, air temperature at 1.22 meters (4 ft.), wind velocity, and general weather conditions including rainfall amounts and interval after treatment.

Grasshopper populations, including dominant species and life cycle stages, immediately prior to treatment, three and seven days after treatment.

Plant response, phytotoxicity and other observations.

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Range Caterpillar

The range caterpillar, *Hemileuca oliviae* Cockerell, feeds primarily on range grasses in areas in northeastern and south central New Mexico at elevations between 1734 and 2438 meters (4,700 and 8,000 feet). The infestation has extended into southeastern Colorado and the western edge of the Texas Panhandle. Range caterpillars consume large amounts of foliage, waste additional unconsumed parts of leaves and cause other foliage to be ungrazed because of the presence of irritating spines on the active larvae and cast skins (Hewitt et al. 1974). Heavy populations may destroy all grass down to the crown, producing conditions conducive to wind and water erosion.

Crop and Location of Tests:--Species composition of the vegetation and the terrain are usually dictated by the location of economic infestations of the pest. Care should be given to uniformity of vegetation and terrain among treatments. Proximity to watering sites will affect forage utilization and distribution of livestock.

Experimental Design:--Since migration is limited in the early instars, plot size can be considerably smaller than is required when the caterpillars are large. Migration by large caterpillars is increased as the density of the population and percentage of standing crop foliage consumed increases.

For small worms, plots should be at least three swaths wide by 402.2 meters (¼ mile) in length. For larger worms, the plot width should be at least doubled. To reduce drift, plots should be separated by an adequate distance which will depend on wind velocity and direction.

Plots as small as 2.43 hectares (6 acres) have been used for efficacy tests by airplane against first and second instars.

Watts et al. (unpublished data) has experimented with circular arenas encompassing approximately 4.18 m^2 (5 yd^2) to confine known numbers of small caterpillars within the test plots on an experimental basis to reduce variation in density. These arenas were made of six inch strips of tin forced ca 2.54 cm (1 in.) into the soil. Larger plots, from 20.25 to 259.2 hectares (50 to 640 acres) have been used on other studies in New

Mexico. Coppeck (unpublished data) conducted preliminary screening tests with a compressed air hand sprayer on small plots.

Application and Equipment:--Aerial application equipment that is designed for the aircraft being used should be properly calibrated. Aircraft designation; boom size and length; number, size of nozzle, or atomizers and position on aircraft; pressure; aircraft speed; altitude and swath width; type of solvent; concentration of solution and quantity of solution used should be reported. Dye cards for evaluation of deposit uniformity are recommended. Flight runs made crosswind usually increase the uniformity of deposits. Applications should be made under conditions that avoid excessive convection currents.

Sampling:--Population densities are usually evaluated by counting the number of caterpillars in square yard sampling areas located well within the plot. Various sampling schemes, designed to remove bias and assure coverage of an adequate area, have been used. The sampling scheme used should assure that an entire swath width and preferably more be included in the area to be sampled. A minimum of 10.84 m^2 (1-yd^2) samples or more, until at least 50 worms are counted, is needed per plot. Additional samples will increase precision. When 5, 4.18 m^2 (5 yd^2) arenas are used, 100 caterpillars per arena should be used.

Because of the habits of the range caterpillar, the accuracy of visual counts is increased by delaying initiation of counting until midmorning when ground temperatures have increased enough to initiate activity in the caterpillars.

Counts should be taken immediately prior to treatment and at intervals estimated to embrace partial and maximum kill.

Analysis and Reporting of Data:--Where possible, treatment means should be compared using a valid statistical test for significance. The standard material used in private-state-federal control programs in the geographic area should be included. Replicated untreated plots are also recommended.

The following data should be reported:

Description of terrain and dominant vegetation, including plant height, stage and condition at time of treatment.

Insecticide formulation used, kilograms active toxicant/hectare and liters/hectare of spray.

Describe equipment in detail (type of aircraft or application equipment, speed, height, swath width, type, number and arrangement of nozzles or other apparatus, etc.).

Ground surface temperature, air temperature at 1.62 m (4 ft.), wind velocity and general weather conditions including rainfall amounts and interval after treatment.

Range caterpillar populations, including composition by instars, immediately prior to treatment and at intervals to measure partial and maximum population reduction.

Plant response, phytotoxicity and other observations.

References

Hewitt, G. B., E. W. Huddleston, Robert J. Lavigne, D. N. Veckert, and J. G. Watts. 1974. Rangeland Entomology. *Range Sci.* Ser. 2, 127 pp.

Watts, J. G. 1975. Professor of Entomology, Department of Botany and Entomology, New Mexico State University. Personal communication.

Harvester Ants

Harvester ants of the genus *Pogonomyrmex* denude areas around their nests. When colonies are vigorous and numerous, control efforts may be initiated.

Crop Variety and Location of Tests:--Areas chosen should be representative of the region for which control recommendations are needed. Accurate ant species determination is necessary because of the variation in the habits of harvester ants. Lavigne (1966), in southeast Wyoming found that equally effective control, at least with mirex could be obtained by treating any time between the end of May and the end of August, which is during the season when ants are actively foraging. Knowlton (personal communication) feels that more effective control is obtained by treating in the spring in Utah. Lavigne (personal communication) recommends that baits be applied in the morning since harvester ants are often inactive during midday. He further states that baits applied in the evening are subject to small mammal feeding, especially ground squirrel.

Experimental Design:--Preliminary screening has most often been accomplished by individual mound treatment with baits, dusts or EC formulation mixed with water. Because of the variation in colony vigor, size and foraging, large numbers of replicates are needed. Untreated control nests should be located at an adequate distance to prevent foraging from a treated area. Complete overlap in foraging between adjacent nests has been shown to occur when *Pogonomyrmex owyheei* mound density was high (Willard and Crowell 1965).

Race (1966) used 40.5 hectare (100 acre) plots separated by untreated buffer zones of 152.4 meters (500 ft.) for aerial application of baits. Plots of 40.5 hectares (100 acres) have also been used by Lavigne (unpublished data). Smaller plots could obviously be used for aerial application of baits or sprays.

Replicated, untreated check plots should be included in the experimental design.

Application Equipment:--Simple measuring devices are used for individual mound treatment. For larger plots, hand spreading or an electric powered cyclone seeder mounted on a vehicle have been used (Crowell 1963). Bait dispersal by aircraft requires equipment designed, evaluated and calibrated for the type of aircraft used. Race (1965) treated large plots with a Stearman 650 HP aircraft equipped with a "Swathmaster" to spread the bait. Lavigne (unpublished data) used a Super Cub (PA-18A) equipped with a similar metered spreader made by Avery Aviation, Inc.

Sampling:--Control evaluations should be made in the spring of the year following application. Lavigne (1966) excavated every mound in individually treated mound tests. Race (1965) excavated 50 mounds in each 40.5 hectare (100 acre) plot and used an index of control to improve precision in evaluation of efficacy. Lavigne (unpublished data) excavated 100 mounds in the same size plots. He also evaluated the degree of reinfestation. Mound abandonment with or without subsequent invasion of treated mounds is possible (Crowell 1963, Lavigne 1966). Another factor to be considered is that there is a single queen in harvester ant colonies and no queen replacement is apparently possible.

Analysis and Reporting of Data:--Treatment means should be compared using a valid statistical test for significance.

The following data should be reported:

Insecticide formulation; diluent and dilution, and amount of active toxicant and total mix per nest or hectare.

For baits, include name of bait, source and composition.

Plot size, layout, mound density and size or vigor, and species of harvester ant involved.

Percent control on the basis of dead colonies or an index by degree of control.

References

Crowell, H. H. 1963. Control of the western harvester ant, *Pogonomyrmex occidentalis* with poisoned baits. *J. Econ. Entomol.* 56:295-8.

Knowlton, G. F. 1975. Professor of Entomology, Emeritus, Department of Biology, Utah State University. Personal communication.

Lavigne, R. J. 1966. Individual mound treatments for control of the western harvester ant, *Pogonomyrmex occidentalis* in Wyoming. *J. Econ. Entomol.* 59:525-32.

Lavigne, R. J. 1975. Professor of Entomology, Entomology Section, Division of Plant Sciences, University of Wyoming. Personal communication.

Lavigne, R. J., and H. G. Fisser. 1966. Controlling Western Harvester Ants. Mountain States Regional Publication 3, 4 p.

Race, S. R. 1964. Individual colony control of the western harvester ant, *Pogonomyrmex occidentalis*. *J. Econ. Entomol.* 57:860-4.

Willard, J. R., and H. H. Crowell. 1965. Biological activities of the harvester ant, *Pogonomyrmex owyheei* in central Oregon. *J. Econ. Entomol.* 58:484-89.

Imported Fire Ant

Crop Variety and Location of Tests:--Experiments should be conducted on heavily infested areas typical of the area for which control recommendations are to be made.

Experimental Design:--At least two replicates with several subplots per replicate are desirable. Untreated and/or a standard insecticide treatment should be used.

Minimum plot size for ground application is determined by migration from untreated areas, crossfeeding, or from plots where poor control is obtained. Markin and Hill (1971) used .405 hectare (one acre) plots isolated with 15.2 meter (50 ft.) wide chemically treated borders to prevent migration; however, this did not prevent new queens from flying into the area after treatment and establishing new colonies. Lofgren et al. (1963) and in personal communication recommended 2.43 to 3.24 hectare (6 to 8 acre) plots with 3, .405 hectare (one acre) sampling subplots within the large plots. For aerial plots, Markin and Hill (1971) used 8.1 hectare (20 acre) plots with 10 randomly chosen .08 hectare (1/5 acre) circular subplots for counting.

Application and Equipment:--Hand operated Cyclone seeders, power-take-off model Cyclone seeders, Gandy fertilizer distributors and a Buffalo turbine blower have been used to distribute dry materials. Slurry type baits have been applied by a specially designed applicator which pumped bait out each end of a 4.05 meter (10 ft.) boom and dropped the slurry directly to the ground in strips 4.05 meters (10 ft.) apart (Lofgren et al. 1961, Lofgren et al. 1963). Microencapsulated oil baits have been applied with a specially designed spreader (Markin et al. 1969). This apparatus was enlarged and adapted for aircraft application (Markin and

Hill 1971). Banks et al. (1972) used aircraft equipped with the Texas A&M type spreader and a special spreader from the Aircraft Operations Section, Plant Protection Division, ARS-USDA.

Sampling:--Control is usually determined by the percent reduction in active mounds based on a pretreatment count of all active mounds in one acre plots or .08 to .405 hectare (1/5 to 1 acre) subplots within larger areas. Lofgren et al. (1963) considered mounds active if more than 20 workers or a wingless queen and less than 20 workers were found. Banks et al. (1972) opened mounds with a shovel. Markin and Hill took pretreatment counts, mapped all mounds and sampled at 10 and 22 weeks. Other workers have increased sampling intensity beginning as early as 2 weeks and continuing for up to 26 weeks.

Analysis and Reporting of Data:--Where possible, treatment means should be compared using a valid statistical test for significance.

The following data should be reported:

Description of terrain and dominant vegetation including plant height, density, stage and condition at time of treatment.

Insecticide formulation used, amount of active toxicant per hectare, name, source, and composition of baits.

General weather conditions at time of application and rainfall during evaluation.

Mound density and percent reduction in active mounds at intervals after application.

References

Banks, W. A., G. P. Markin, J. W. Summerlin, and C. S. Lofgren. 1972. Four Mirex bait formulations for control of red imported fire ant. *J. Econ. Entomol.* 65:1468-70.

Lofgren, C. S., V. E. Adler, and W. F. Barthel. 1961. Effect of some variations in forumlation or application procedure on control of the imported fire ant with granular heptachlor. *J. Econ. Entomol.* 54:45-47.

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Markin, G. P., C. J. Mauffray, and D. J. Adams. 1969. A Granular Applicator for Very Low-volumes of Microencapsulated Insect Bait or Other Materials. U. S. Dept. Agr. ARS (Ser.) 81-84. 4 p.

Markin, G. P., and S. O. Hill. 1971. Microencapsulated oil bait for control of the imported fire ant. *J. Econ. Entomol.* 64:193-196.

Black Grass Bugs - *Labops* and *Irbisia*

Grass bugs have been recognized recently as major pests of range grasses, especially introduced species, in restricted areas of most of the western states. Early symptoms of damage are yellow or whitish irregular spots on the leaves which, with continued feeding, become more numerous, coalesce, and the leaves dry out and die.

Crop Variety and Location of Tests:--Areas chosen should be representative of the region for which control recommendations are needed. Experiments should be conducted on moderately to heavily infested range on which the previous grazing history is known.

Experimental Design:--Since migration appears to be less than with grasshoppers, plot size can be smaller. Plots of 12.2 x 12.2 meters (40 x 40 ft.), as recommended for plant bugs on alfalfa, should be adequate for ground application. Kamm (personal communication) found 6.1 x 6.1 meters (20 x 20 ft.) plots to be adequate; however, Haws (personal communication) experienced difficulty with drift using 9.1 x 9.1 meters (30 x 30 ft.) plots. A randomized complete block design with a minimum of three replicates is recommended. Care should be exercised that drift does not affect other treatments or the untreated check. The use of treated borders around plots will reduce migration where this is a problem.

The minimum size for aerial application plots will be dictated by the type of equipment used. The distance between plots or the width of plots should be adequate to prevent drift as grass bug populations appear to be very susceptible (Haws, personal communication).

Application and Equipment:--Low pressure low-volume boom type sprayers can be used where terrain permits. Preliminary screening tests may be conducted with knapsack or compressed air sprayers as long as coverage is thorough. For aerial application, properly calibrated application equipment designed and evaluated on the type of aircraft being used is recommended. ULV formulations are usually the most suitable for aerial application.

Sampling:--No standardized one-step sampling technique has been developed which is effective for all instars. The standard 3.8 decimeter (15 inch) insect net has been used for sampling adults and larger instars. Sweep net samples vary in efficiency depending upon the growth habits of the grass species being sampled. Temperature, time of day, cloud cover, and other variables have a profound effect on the sampling under similar conditions. Haws (personal communication) reports that disturbance of the grass during sampling causes grass bugs to drop from the plants. Todd and Kamm (1974) and Haws (personal communication) have used modifications of a sampling cylinder from which specimens were aspirated and in some cases the vegetation was also placed in Berlese funnels for further specimen recovery.

Analysis and Reporting of Data:-- Treatment means should be compared using a valid statistical test for significance.

The following data should be reported:

Description of terrain and dominant vegetation, including plant height, stage and condition at time of treatment.

Insecticide formulation used and amount of active toxicant per hectare.

Amount of spray per hectare, type of equipment and operating parameters.

Temperature and general weather conditions at time of treatment.

Rainfall amounts and interval from application, especially for first 24 hours.

Insect population counts recorded as number of insect per sweep or unit of measurement in the vacuum net technique. The dominant species or species composition of the grass bug population.

References

Haws, B. A. 1975. Professor of Entomology, Department of Biology, Utah State University. Personal communication.

Haws, B. A., D. D. Dwyer, and M. G. Anderson. 1973. Problems with range grasses: Look for black grass bugs. *Utah Sci.* Vol. 34 March.

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Knowlton, G.F. 1966. Grass Bugs: Range and Crop Pest in Utah. Utah State Univ. Ext. Serv. Entomol. Mimeo Ser. 119.

Knowlton, G. F. 1975. Professor of Entomology, Emeritus, Department of Biology, Utah State University. Personal communication.

Todd, J. G., and J. A. Kamm. 1974. Biology and impact of a grass bug *Labops hesperius* Uhler in Oregon rangeland. *J. Range Manage.* 27: 453-458.

Chigger, *Neoschongastia Americana* (Hirst) (Affecting Turkeys)

Kung et al. (1969) described the damage of this pest by stating, "The chigger, *Neoschongastia americana* (Hirst) attacks turkeys in range pens in many areas of the southern United States. Since the larva feeds at the site of attachment, the area becomes inflamed and forms a purulent lesion. The lesion causes a skin blemish which must be removed when the turkey is processed. The necessary trimming causes the turkey carcus to be downgraded."

Crop Variety and Location of Tests:--Since heaviest populations are found on soils that tend to crack when dry and on soils with rock outcroppings, these soil types should be selected. Sandy soils may not support adequate populations for evaluation of insecticide efficacy (Price and Kunz 1970).

Experimental Design:--Chigger populations as determined by the number of lesions per turkey are highly variable. At least three and preferably more replicates are needed. Because of the habits of turkeys resting along the edges of pens, 4.6 to 6.1 meters (15 to 20 ft.), treated borders are necessary around the pens containing turkeys on the experimental plots.

Price and co-workers used wire pens of .0035 to .0034 hectare (1/116 to 1/120 acre) to confine 8 to 12-week old turkeys on treated areas. The plots were cleared of vegetation prior to treatment. Treated barriers of 4.6 to 6.1 meters (15 to 20 ft.) were found to be required to achieve maximum control. In other studies, .02 hectare (1/20 acre) pens stocked 10 turkeys, 22.8 x 22.8 meter (75 x 75 ft.) plots with pens 13.7 x 13.7 meters (45 x 45 ft.) stocked with 50 turkeys and .405 hectare (one acre) plots with nine 4.3 x 4.3 meter (14 x 14 ft.) pens stocked with three turkeys each and placed in an X configuration within the plot, were used (Price and Kunz 1970, Price et al. 1970).

Replicated untreated check plots should be included in the experimental design. Experiments may need to be designed to evaluate serial treatments on the same plot.

Application Equipment:--Small plots have been treated with water sprinkling cans for liquids, fabricated shakers for granules and commercially made portable hand dusters. Larger plots have been treated with pressure sprayers at 8.8-10.6 kg/cm^2 (125-150 psi) at the rate of 3741.6 liters/ha (400 gal. of water/acre). (Price and Kunz 1970, Price et al. 1970).

Sampling:--Indirect counts, based on the number of chigger lesions per bird were used in the studies cited above.

The number of lesions on the drumsticks, thighs and breast areas were counted for each bird. Counts were made weekly for 7 to 20 weeks. Price et al. (1970) did not make weekly counts; instead, grade as determined by a Federal meat inspector was used as the criterion of success or failure of the insecticide.

Analysis and Reporting of Data:--Treatment means should be compared using a valid statistical test for significance.

The following data should be reported:

Insecticide formulation used and amount of active toxicant per hectare.

Amount of spray, dust or granules per hectare and the type of equipment used.

Plot size and lay out, including any special vegetation clearing and number and age of turkeys stocked.

Temperature and general weather conditions at the time of treatment.

Rainfall amounts and intervals after treatment.

Number of lesions per bird or other index of infestation in treated and untreated plots at each sampling interval.

References

Kunz, S. E., M. A. Price, and O. H. Graham. 1969. Biology and economic importance of the chigger, *Neoschongastia americana* on turkeys. *J. Econ. Entomol.* 62:872-875.

Price, M.A. 1975. Professor of Entomology, Department of Entomology, Texas A&M University. Personal communication.

Price, M.A., and S. E. Kunz. 1970. Insecticidal screening for chemicals to control the chigger, *Neoschongastia americana* (Hirst) on turkeys. *J. Econ. Entomol.* 63:373-6.

Price, M.A., S.E. Kunz, and Jesse J. Matter. 1970. Use of Dursban® to control *Neoschongastia americana*, a turkey chigger, in experimental pens. *J. Econ. Entomol.* 63:377-379.

VEGETABLES (FIELD GROWN)

CRUCIFERAE

Crops in this group include: Cabbage - *Brassica oleracea* var. *capitata*: Broccoli - *Brassica oleracea* var. *botrytis*: Cauliflower - *Brassica oleracea* var. *botrytis*; Brussels sprouts - *Brassica oleracea* var. *gemmifera*: Kale - *Brassica oleracea* var. *ocephala*; Collards - *Brassica oleracea* var. *virdis*: Turnip - *Brassica campestris* var. *rapa*: Mustard - *Brassica juncea* var. *crispifolia*; Spinach - *Spinacia oleracea*.

Cabbage Looper (#1) *Trichoplusia ni* (Hubner) and Associated Insects

The cabbage looper, *Trichoplusia ni* (Hubner), is without question the number one pest of this group. During the 1950's and much of the 1960's, growers of these crops in many sections of the country were without adequate looper insecticides. Residue problems, precluding the release of new chemicals and removal of some previously labeled, the development of resistance and higher consumer standards--all contributed to an almost untenable situation. With the appearance of improved strains of the safe bacterium, *Bacillus thuringiensis* Berliner, and approval of new insecticides such as methomyl and methamidophos there is now hope of eventual success in looper control. In addition, the use of viruses, sex attractants, chemosterilants and other physiological and biological methods show great promise for the future. However, constant investigations for improved measures against loopers are necessary and will continue to be one of the most active areas in insect control.

Although test procedures for cabbage loopers will be stressed, there are a number of other insects that may be sampled and recorded using the same basic test structures. Some of these associated pests are as follows: Imported cabbage worm, *Pieris rapae* (Linnaeus): diamondback, *Plutella xylostella* (Linnaeus): fall armyworm, *Spodoptera frugiperda* (J.E. Smith): beet armyworm, *Spodoptera exigua* (Hubner): Garden webworm, *Loxostege rantalis* (Guenee), Hawaiian beet webworm, *Hymenia recurvalis* (Fabricius), and corn earworm, *Heliothis zea* (Boddie).

Both foliage sprays and systemic granulars applied to the soil will be covered.

Crop and Location of Tests:--Select a variety or varieties commonly grown in the area in question. A uniform test is desirable since the degree of control or plant response may vary in different soil types. Follow proven planting techniques and cultural practices.

Experimental Design:--

Ground Application-A randomized complete block design with three or more replications per treatment is suggested. Ideally, candidate insecticide performance should be compared with untreated plots and one or more standard insecticides recommended for the area in question. However, if it is impossible to have untreated controls, it should be sufficient to compare the treatments with one or more of the recommended standards.

Plot size may vary greatly depending on the uniformity of infestation and population density. A number of investigators have used single row 7.6-15.2 m (25-50 ft.) long plots with success; Boling (1972), Chalfant and Brett (1965), Chalfant et al. (1973), Creighton et al. (1971, 1974) and Shorey (1963). Kouskolekas and Harper (1973) utilized 9.1-12.2 (30-40 ft.) long plots with 4-5 rows. Davis and Kuhr (1974), Greene and Workman (1971), and Judge and McEwen (1970) made observations on multiple row 15.2 m (50 ft.) long plots.

One or more adjacent untreated rows would appear to be essential to 1 and 2 row plots and highly desirable in larger test areas. Davis and Kuhr (1974) planted 2 rows of corn next to their 2 row plots. Hofmaster and Waterfield (unpublished data at the Virginia Truck and Ornamentals Research Station, Painter, Virginia) worked with 1-3 row plots 10.7-15.2 m (35-50 ft.) long which were bounded by 1-3 untreated rows, thereby affording increased insect pressure and minimizing cross contamination.

Aerial Application-A minimum of 2 and preferably 3 swaths, each 12.2 m (40 ft.) wide or covering a comparable area is suggested to prevent drift and have sufficient area in the middle of the plot to collect representative samples. The length should be sufficient to enable the pilot to fly level and safely over the plots for at least 182.6 m (600 ft.).

Application and Equipment:--Both sprays and granular applications should be utilized in investigating insect control and can be adapted to most of the species concerned.

Ground Application-Knapsack sprayers operating at 2.1-4.2 kg/cm^2 (30-60 psi) and delivering 187.1-935.4 liters/ha (20-100 gallons of water/acre) will give satisfactory results (Shorey 1963, Creighton et al. 1971). Calibrate the sprayers carefully and apply the spray along each side of the row and over the top. Where single nozzles are used this will require a trip along each side and back over the top. Backpack sprayers may have a spray boom equipped with 3 nozzles per row. These nozzles should be adjusted so as to cover the top and sides of each row (Hofmaster and Waterfield 1972).

In moving to mechanized equipment, a wide variety of pressures and rates are encountered, e.g., Judge and McEwen (1970) 261.9 liters/ha (28 gallons/acre) at 4.2 kg/cm^2 (60 psi); Greene and Workman (1971) 935.4 liters/ha at 17.6 kg/cm^2 (250 psi): and Kouskolekas and Harper (1973) 935.4 liters/ha (100 gallons/acre at 38.7 kg/cm^2 (550 psi)). Generally speaking, the type of application equipment is of secondary importance if good coverage is obtained.

When working with large plots it is suggested that the treatments be applied with equipment that is adaptable to that particular locality. Such procedure will do much to decrease the danger of subsequent failure should a product be labeled for a given method that is not generally followed or cannot be followed in a particular section.

Granules may be applied by a variety of methods. One of the most commonly used is as a soil sidedress, either at planting, transplanting, or later in the season. Commercial applicators may be used satisfactorily. Calibrate the applicator carefully for each formulation and then treat directly without resetting. Hale and Shorey (1972) applied granules with a tractor-mounted belt planter by side-dressing 7.6-10.2 cm (3-4 in.) from the plant row and 5.1-7.6 cm (2-3 in.) deep. Plants were 7.6-15.2 cm (3-6 in.) high at the time of planting and irrigation was applied within 24 hours.

Aerial Application-Use nozzle arrangement and volume of finished spray determined to be practical under existing conditions. In most areas the spray volume will range from 18.7-93.5 liters/ha (2-10 gallons/acre) although good control has been obtained with lower or higher dosages.

Regardless of the method of application, the equipment should be thoroughly cleaned before each use. When changing treatments, the tank, boom and nozzles should be rinsed with water run through the entire system until it is clear.

If more than one rate (kg/ha or lbs/acre) of toxicant is used, start the test sequences with the lowest rate thereby keeping the chances of contamination at a minimum. Generally, several rates should be applied when testing is in the initial phase. After the rate or rate range is established and testing is in the final stages, emphasis should be placed on the probable rate or rates to be used.

Sampling:--Make direct counts of larvae, checking at least 10-25 plants or parts therefrom/plot (Creighton et al. 1971, 1974, Chalfant and Brett 1965, Chalfant et al. 1973, Greene and Workman 1971). A clearer understanding will be obtained if the surviving loopers are grouped according to size. Hale and Shorey (1972) recorded the loopers as: small (1st stage): medium (2nd to early 4th); and large (late 4th and 5th stages).

Be prepared to supplement direct counts with ratings of injury. This can be especially important when a naturally occurring nuclear polyhedrosis virus decimates the existing population in a space of 4-5 days (Hofmaster 1961).

Various ratings may be employed: Kouskolekas and Harper (1973) adopted a 1 to 10 scale; Greene et al. (1969) working on a cooperative cabbage looper control program in Florida used a damage rating scale of 1 to 6; Greene and Workman (1971) adapted this 1 to 6 rating on a leaf crop (collards): Creighton and McFadden (1974) examined the edible leaves of each plant (collards), recorded the number of injured and uninjured leaves, and used these to calculate the percentage of plants that were either uninjured or had 1 leaf, 2-10 leaves or more than 10 leaves injured; and Ratcliffe et al. (1961) adapted a weighted injury index in which values were assigned to various classes of injury, multiplied by the number of plants in that class and divided by the total number of plants checked. Whatever the rating method, be explicit. Do not use terminology such as medium, severe, etc. without clearly spelling out just what these terms encompass.

Take yield records, carefully noting the extent of injury to the marketable parts of the plant at harvest. Records may be taken from the entire plot or representative section therefrom. Separate crop into marketable and unmarketable classification similar to the method of Reid (1940) for cabbage: Class 1 - head and 4 wrapper leaves free of all feeding; Class 2 - plants with some caterpillar injury but eligible to U.S. Grade 1; and Class 3 - head and 4 wrapper leaves extensively damaged by feeding and ineligible to U.S. Grade 1.

Analysis and Reporting of Data:--Compare treatment means using a valid statistical method such as Duncan's multiple range test. Candidate insecticide performance should be compared with replicated untreated plots and one or more standard insecticides recommended for the area. Where it is impossible to leave untreated areas, comparison with one or more standard insecticides should suffice.

The following data should be reported:

1. Pre-test counts to determine approximate level of the population prior to treatment. It is realized that this will not be possible for some types of insects.
2. Insecticide formulation used and kilograms active toxicant/hectare (lbs active/acre). Describe application equipment, quantity delivered, pressure, etc.
3. Insect populations and stage of plant growth on given date, listing sampling technique.
4. Plant height, stage and condition at time of treatment and sampling.
5. Temperature, humidity, rainfall and general weather conditions at treatment. Record these for all application dates and all except humidity for the sampling dates. Overall weather records for the entire test period may be useful.
6. Percent organic matter and type of soil.
7. Plant response, phytotoxicity or obvious defects in the harvested crop.

Harlequin Bug *(Murgantia histrionica)* (Hahn)

The harlequin or "fire bug," *Murgantia histrionica* (Hahn), has been called the most important insect enemy of cabbage, collards and related crops in the southern half of the U.S. It sucks the sap from the plants, injecting toxic saliva and apparently poisoning them as it does so, as damage is far out of proportion to the number of bugs or juices withdrawn. Damage first appears as chlorotic spots but these areas soon turn brown and die. Severely injured plants wither and appear as if scalded. Published references concerning harlequin control are quite limited.

Sampling:--Make direct counts of both adults and nymphs on 10-25 plants/plot, keeping the two classes separate. Where populations are low, 50 or more nymphs may be carefully counted on the plants, the section of the row can be isolated and the treatments applied (Hofmaster 1959) for determining mortality.

Supplement with observations on the number of characteristic keg-shaped egg masses.

Record plant condition throughout the season; either through ratings or actual counts of the harlequin bugs or their feeding scars.

Collect yield records. Record marketable and unmarketable heads or leaves and their weights. Yields may be from the entire plot or representative sections therefrom.

Flea Beetles

A number of species of flea beetles attack crops of this group. The striped cabbage flea beetle, *Phyllotreta striolata* (Fabricius): the western striped flea beetle, *Phyllotreta ramosa* (Crotch); the western black flea beetle, *Phyllotreta pusilla* (Horn): the sinuate striped flea beetle, *Phyllotreta sinuata* (Stephens): and the spinach flea beetle, *Disonycha xanthomelas* (Dalman) are some of these.

Flea beetles vary greatly in life history and while the larvae of most species develop in the soil, some of the young feed on or in the foliage. Examples of foliage feeding larvae include the sinuate striped flea beetle and spinach flea beetle. Although the flea beetle larvae cause damage, most of the injury is by the adults. Seedling plants of this group are especially vulnerable to damage by flea beetles and plant stands may be seriously reduced in a day or so.

Sampling:--Select at least 25 leaves/plot and count the flea beetle feeding scars thereon. If damage is heavy, count uniform sections of the leaf. Some investigators such as Ratcliffe et al. (1961) prefer to count all the beetles on a plant but this is difficult unless a sampling cage (Hills 1933) is used. Make larval counts of species that develop on the foliage. Sweeping is discouraged as an accurate means of evaluation.

On seedlings, count the number of injured plants/0.305 m (1 ft.) of row. Stand counts may be needed where infestations are severe. If the plants have several leaflets it may be possible to check 100 or more leaflets/plot. On calm days, actual counts of beetles/10-25 samples of 0.305 m (1 ft.) of row may be advantageous. A sampling cage (Hills 1933) may be used to advantage.

Take yields, using methods that are most appropriate for the crop. Yields may be from the entire plot or representative areas therefrom.

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CRUCIFERAE AND HEAD LETTUCE

Aphids and Thrips

Crop and Location of Tests:--Select a crop variety that is grown commercially in a suitable test area that is protected from pesticide drift from any adjoining fields, i.e., having the test area upwind from the adjoining field should be sufficient. Aphids and thrips should be considered economically important in the test area.

The plot size should depend on the stage of pesticide development. In the early stages small hand and ground equipment applications will suffice to demonstrate efficacy. Plots one row wide by 7.6-15.2 m (25-50 ft.) long with 1-2 untreated buffer rows between each plot should be large enough for small "screening" tests.

In the final stages of pesticide development the plot size should be larger to more closely resemble the commercial ground and air applications, and large enough to prevent drift from adjacent plots from influencing the results in the sampling area.

Since most commercial plantings of cruciferae and lettuce are double row beds, it is suggested that experimental pesticide plots be conducted on double row beds as it is much more difficult to obtain coverage in comparison to single row beds. Most commercial ground applicators treat 6-8 beds per swath, therefore, plots should be 12-16 beds wide by 18.3 m (60 ft.) long.

Air plots should be 36.6 m (120 ft.) wide or 3 swaths 12.2 m (40 ft.) in width to prevent drift and to have enough area in the middle of the plots to make aphid and thrip counts over a wide area. The length must be long enough to enable the pilot to fly level and safely over the plots for at least 182.9 m (600 ft.).

Experimental Design:--Use a randomized complete block design. Use at least three replications when applied by ground equipment. When applied by air, two replications will suffice when populations of aphids (apterous) and thrips are fairly evenly distributed throughout the test area. However, more replications should be used whenever possible.

Plots should be staked and mapped in any numbering system that will conceal as much as possible the identity of individual treatments when plot evaluations are made. One suggested method would be to number and stake the plots in consecutive order. (For example, 1-30.) Then give each treatment a letter that would correspond to two or more of the numbered plots, depending on the number of replications. Treatment "a" for example might be applied in plot 3, 11, etc.

Application and Equipment:--Untreated controls should be used to determine the aphid and thrip severity and to provide a basis of comparison of the treatments. Also apply the recognized standard to provide a basis of comparison. If it is impossible to have untreated controls because of the large acreage involved, it should be sufficient to compare the treatments with one or more acceptable standard materials.

Equipment should be thoroughly cleaned before each use. Between each treatment the tanks, boom and nozzles should be rinsed and clean water run through the system until the water comes out clear. If more than one rate (AI/A) of the same material and the same formulation are being tested, start the test sequence with the lowest rate so that the chances of contamination are kept at a minimum.

A row crop boom attached to any acceptable foliar spray ground equipment should be used for proper coverage. There are many types of spray tips that can be used. It is suggested that conejet cone spray tips (TX series) be used when low capacity spray volume is needed. The small particle size provides maximum distribution of the pesticide. When higher pressures and flow rates are needed, then the disk cone spray tip should be used. There are situations when the best method is a flat fan type tip directed over the center of the plant row. This will provide deeper penetration into the plant foliage. The drop side spray tips could then be the disk type. The nozzles can be mounted on drop pipes suspended from the boom. Three nozzles per row is suggested when plants are small. As the plants grow, the number of nozzles should increase to provide optimum coverage. Regardless of the number of nozzles per row, the spray pattern from the side tips should be directed in such a way as to apply as much pesticide as possible to the underside of the leaves. When small screening tests are applied, knapsack sprayers operating at 2.1-4.2 kg/cm^2 (30-60 psi) will give satisfactory results. The boom should have 3 nozzles per row. Air application equipment should be commercially acceptable.

Granules-Many methods of granule placement are possible. It is suggested that two methods be used. Placing the granules directly in the furrow at planting time, or applied as a side-dress (with fertilizer saves labor costs) 7.6-10.2 cm (3-4 in.) deep and 5.1-10.2 cm (2-3 in.) to one side of the plant row.

The rate of application is dependent on the stage of pesticide development. Two to three rates (AI/A) should be used when testing is in its initial phase. After the most efficient rate has been established and the pesticide is in the final stages of development, then emphasis should be placed on the probable rate or rates (AI/A) to be used.

The finished spray volume per acre would be dependent on the size of the lettuce plants. When foliar spray is applied by small hand or large ground equipment, 113.6-227.1 liters/ha (30-60 gals./acre) will give satisfactory results. When foliar spray is applied by air, 37.9-56.8 liters/ha (10-15 gals/acre) will provide good results.

The time of application should be when aphids and thrips first appear in any numbers that represent fairly closely an economic infestation.

Since the control of aphids and thrips mostly requires a remedial type treatment or treatments, the testing of pesticides to control aphids and thrips is a "one application" type screening method. The second application, if requested, would follow when the effectiveness of the initial application is gone.

One to three days is suggested as the initial interval between treatment and observations, and then every 4-7 days thereafter until control in all plots is no longer considered economic, unless of course specific intervals are requested.

Sampling:--Count the total number of apterous aphids on 5-10 plants per plot. The number of plants would depend on the severity of the infestation. The small size and quick movement of thrips prevent the use of accurate visual leaf counts. More than one method of counting thrips can be used, including shaking the plants over jars containing alcohol and selecting leaves at random and placing them in alcohol jars for counting in the laboratory. It is suggested that the best method would be the use of a "Burlese." This would involve selecting plants or leaves at random and placing them in the burlese where heat and light drive the thrip from the leaves down to the alcohol jars where they can be counted at the convenience of the investigator. This method can also be used for aphids and gives more accuracy to the data. When making counts, care should be taken to keep within a well buffered zone. When examining small single row hand plots, keep at least 1.5 m (5 ft.) away from the end of the plot.

The crop on which any new pesticide is being tested should be examined at least once to determine if there is any deterimental effect on yield. This is especially important when the pesticide is applied during the early stages of plant development. All mature cruciferae and lettuce heads in a given area of the central part of the plot should be harvested. Marketable heads should be put in field cartons and the data converted to "yield in cartons per hectare (acre)."

Any type of phytoxicity such as stunting, leaf burn and chlorosis and the percent of damage should be reported.

Analysis and Reporting of Data:--Data means should be compared using any valid statistical test for significance such as Duncan's new multiple range at the 5% level.

The following information should be included in reporting test results:

Product name and formulation used.
Crop (variety) treated.
Location of the test.
Type of irrigation used (furrow or sprinkler).
Plot size.
Number of replications.
Active ingredient kg/ha (lb/acre).
Finished spray volume l/ha (gal./acre).
Method of application.

Stage of crop growth.
Treatment dates.
Evaluation technique.
Sampling technique.
Number of samples taken.
Total insect counts per plot.
Phytotoxicity.
Comments regarding unusual test conditions or performance.
Temperature and general weather conditions at time of treatment.
Rainfall or any unusual weather conditions following the application.
Include comment on performance as related to commercial acceptability.
Statistical analysis.

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Cabbage Looper (#2) *Trichoplusia ni* (Hubner)

Most of the following methodology will also apply to the following pests on cruciferae and head lettuce: imported cabbageworm, armyworms, diamond-backs, and beet armyworms.

Crop and Location of Tests:--See statement under Aphids and Thrips. Only modifications are noted below.

In the early stages of pesticide testing, small hand and ground equipment applications would suffice to demonstrate efficacy. Plots one row wide by 7.6 m (25 ft.) long with 1-2 untreated buffer rows between each plot should be large enough since the cabbage looper larva is not very mobile and is very difficult to kill.

Since most commercial ground applicators treat 6-8 beds per swath, plots should be 6-8 beds wide by 15.2-18.3 m (50-60 ft.) long.

Even though treatments by air are not as effective as by ground applications, they do occur and are necessary under conditions of wet fields, etc. Test plots by air should be 36.6 m (120 ft.) wide (3 swaths 12.2 m (40 ft.) in width) to prevent drift, and long enough to enable the pilot to fly level and safely over the plots for at least 182.9 m (600 ft.).

Experimental Design:--See statement under Aphids and Thrips, substitute "larvae" for "aphids (apterous) and thrips."

Application and Equipment:--Only deviations from Aphids and Thrips are noted below.

No method of placing systemic granules in the soil for cabbage looper control has proven to be economically satisfactory. There are many reasons for failure and most can be found by consulting the literature.

The time of application should be when cabbage loopers first appear in any numbers that represent fairly closely an economic infestation. Preferably the population should include small, medium and large size worms. This procedure will test the efficacy of the pesticide against as many stages of the cabbage looper larvae as possible.

Normally, one, three and seven days is suggested as the interval between treatment and observations for the first 3 evaluations and then every 5-7 days until control in all plots is no longer considered economic. This method will provide information on quick initial kill and the longevity effectiveness of the pesticide.

Sampling:--Count the total cabbage looper larvae on at least 10 plants per plot. (If replicated 4 times, this would mean 40 plants per pesticide treatment.) Care should be taken when examining small single row hand plots to keep at least 1.5 m (5 ft.) away from the end of each plot. When plots are commercial ground or air, keep within a well buffered zone.

A better understanding of the effect of each pesticide tested will be obtained if the surviving cabbage looper larvae are counted according to size: Small (1st stage); medium (2nd to early 4th stages); and large (late 4th and 5th stages).

See also the statement under Aphids and Thrips for information concerning yield data and phytotoxicity.

Analysis and Reporting of Data:--See statement under Aphids and Thrips.

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CUCURBITS

Crops in this group include: Cantaloupe - *Cucumis melo* var. *cantalupenis;* Cucumber - *Cucumis sativus;* Pumpkin - *Cucurbita pepo;* Squash - *Cucurbita maxima;* and Watermelon - *Citrullus vulgaris.*

Cucumber Beetles

At least five species of cucumber beetles infest cucurbit plantings in different areas. These are as follows: striped cucumber beetle, *Acalymma vittata* (Fabricius); spotted cucumber beetle, *Diabrotica undecimpunctata howardi* Barber; western spotted cucumber beetle, *Diabrotica undecimpunctata undecimpunctata* Mannerheim; western striped cucumber beetle, *Acalymma trivittata* (Mannerheim); and the banded cucumber beetle, *Diabrotica balteata* LeConte. All have similar habits and life cycles but, in general, the striped cucumber beetle causes more overall injury to cucurbits by direct feeding and transmitting bacterial wilt. Due to the wide distribution and importance of cucumber beetles, test methods for this group will be described first; with slight modifications they can be adapted for other cucurbit pests.

Crop and Location of Tests:--Select a variety or varieties of cucurbits commonly grown in the same geographic area. Brett and Sullivan (1970) have demonstrated a variation in insect susceptibility among cucurbits. If the information is available, plant a more susceptible variety. Follow proven planting and cultural techniques for the area.

Experimental Design:--

Ground Application-A randomized complete-block design with three or more replications is suggested. Ideally, candidate insecticide performance should be compared with untreated plots and one or more standard insecticides recommended for the area in question. However, if it is impossible to have untreated controls, it should be sufficient to compare the treatments with one or more recommended insecticides.

Plot size may vary greatly, depending on the anticipated uniformity of infestation, stage of insect and population density. The following references to plot size are not limited to cucumber beetle investigations but include other cucurbit pests.

Gould (1969), who has conducted extensive cucumber beetle investigations, adapted single row 10.7 m (35 ft.) long plots in rows planted 193-203.2 cm (76-80 in.) apart. Waites and Habeck (1968) treated plots 7.6 m (25 ft.) long by 4 rows wide, while Canerday (1967) selected the same length but varied from 1-3 rows. Roberts and Anderson (1960) used 8 row wide plots 9.1 m (30 ft.) in length. Staples et al. (1967) employed plots 9.1 m (30 ft.) long by 4.6 m (15 ft.) wide containing 12 hills with 3-5 plants/hill. Researchers such as Wright and Decker (1955) used large scale field length plots ranging from 4-16 rows in width.

Aerial Application-A minimum of 2 and preferably 3 swaths each 12.2 m (40 ft.) wide or covering a comparable area is suggested to prevent drift and to have sufficient area in the middle of the plot to collect representative samples. The length should be sufficient to enable the pilot to fly level and safely over the plots for at least 182.6 m (600 ft.)

Application and Equipment:--Both liquid and granular applications should be considered in investigations of cucurbit insect control and can be adapted to most of the species concerned.

Ground Application-Knapsack sprayers operating at 2.1-4.2 kg/cm^2 (30-60 psi) and delivering 187.1-935.4 liters/ha (20-100 gallons/acre) will give satisfactory results. (Canerday 1967, Fisher 1965.) Calibrate the sprayers carefully and apply the spray along each side of the row and over the top. Where single nozzles are used, this will require a trip along each side and back over the top. Backpack sprayers may have a boom equipped with 3 nozzles/row. Regardless of the crop involved, the nozzles should be adjusted so as to cover upper and lower leaf surfaces (Hofmaster and Waterfield 1972).

Due to the many variations possible in spraying techniques on cucurbits, no attempt will be made to standardize, especially in field scale plots. The most practicable end results for large plots will be obtained by utilizing commercial spray practices best adapted to the crop and area concerned.

Regardless of the type of equipment used, repeated and early applications are necessary for the control of cucumber beetles and subsequent reduction of bacterial wilt. For example, Gould (1969) treated the following days after plant emergence: 2, 5, 8, 12, 17 and 24.

Aerial Application-Use nozzle arrangement and volume of finished spray determined to be practical under existing conditions. In most areas the spray volume will range from 18.7-93.5 liters/ha (2-10 gallons/acre) although good insect control has been obtained with lower or higher dosages.

Granules may best be applied with a commercial granular applicator although successful tests have been conducted using a simulated applicator technique (Gould 1969). Be sure to place granules in the same relative position consistently and study placement in detail as much information is needed. Calibrate the granular applicator carefully for each formulation and rate and then treat directly without resetting.

Note: Bees are extremely valuable and essential as pollinators of cucurbits. The effect of the test chemical on the bees should be determined insofar as possible. Harm to the bees will be reduced if treatments are made towards evening.

Regardless of the method of application, the equipment should be thoroughly cleaned before each use. When changing treatments, the tank, boom and nozzles should be rinsed with water run through the entire system until it is clear.

If more than one rate (kg/ha or lbs/acre) of toxicant is used, start the test sequences with the lowest rate thereby keeping the chances of contamination at a minimum. Generally, several rates should be applied when testing is in the initial phase. After the rate or rate range is established and testing is in the final stages, emphasis should be placed on the probable rate or rates to be used.

Sampling:--Evaluations may require a wide variety of observations.

Overwintered Beetles-These beetles work down to the germinating cucurbits and often clip them below ground level. In addition, they transmit bacterial wilt and mosaic and carry the diseases from field to field. Early season control is most important since the bacterial wilt overwinters in the beetles and they are infective at the first feeding.

Make direct counts of overwintered beetles per 10-25 hills/plot. Record bacterial wilt and mosaic as they occur. Gould (1969) measured the average length of vines at thinning time and also checked the incidence of bacterial wilt. Staples et al. (1967) developed a portable cage, with the counter inside, for determining adult populations.

Larvae-If plants appear to be in poor condition later in the season and do not have obvious wilt, it may be from larval damage to the roots. Examine 5-10 hills/plot.

New Adults-Adults present as the fruit nears maturity often gnaw holes in the skin or rind and otherwise scar the fruit. Examine 10-25 fruit/plot, taking special care to check the area in contact with the soil.

Record number and weight of fruit for at least 3 harvests. Records may be taken from the entire plot or representative section therefrom.

Analysis and Reporting of Data:--Compare treatment means using a valid statistical method such as Duncan's multiple-range test. Candidate insecticide performance should be compared with replicated untreated plots and one or more standard insecticides recommended for the area in question. Where it is impossible to leave untreated areas, comparison with one or more standard insecticides should suffice.

The following data should be reported:

1. Pre-test counts, where feasible, to determine approximate level of the insect population prior to treatment. It should be pointed out that this is not possible for some types of insect infestations.
2. Insecticide formulation used and kilograms active toxicant/hectare or lbs. active/acre. Describe application equipment, gallonage, pressure, etc.
3. Insect populations and stage of plant growth on given date, listing sampling technique and units of measurement.
4. Plant height, stage and condition at time of treatment and sampling.
5. Temperature, humidity, rainfall and general weather conditions at treatment. Record these for all applications and all except humidity for the sampling dates. Overall weather records for the entire test period may be useful.
6. Percent organic matter and type of soil.
7. Plant response, phytotoxicity or obvious defects in the harvested crop.

Squash Bug, *Anasa tristis* (De Geer)

The squash bug, *Anasa tristis* De Geer, is a very difficult insect to control. Leaves of attacked plants wilt rapidly, resulting from toxic salivary secretions and appearing almost as though they were literally strangled or poisoned. The margins of the leaves soon become crisp and dead and whole plants may be killed. Later on the fruit is attacked, especially squash and pumpkin in the fields after frost has killed the vines.

Sampling:--Evaluation of squash bug populations is difficult in the adult stage early in the season. Nymphal counts are easier to make and much more accurate overall. Fisher and Green (1965) successfully combined adult and nymphal counts.

Examine 10-25 plants/plot for evidences of adult feeding injury. Record degree, if possible.

As nymphs appear, count the number per 10-25 plants/plot or, if the populations are high, take single leaf samples.

Record the number of squash bugs around 10-25 plants/plot in the fall. Check fruit for injury.

Take yield of marketable and non-marketable fruit, recording number, weight, and injured and malformed fruit. Records may be taken from the entire plot or representative section thereform.

Squash Vine Borer, *Melittia cucurbitae* (Harris)

Control of the squash vine borer, *Melittia cucurbitae* (Harris), must be of a preventive nature as the borers work inside the stems and vines. Make 4 or more weekly applications beginning about the time the vines begin to run (about 4 weeks after planting for bush varieties). Carruth and Howe (1948) have shown a difference in varietal susceptibility to squash vine borers; insofar as possible choose a more susceptible variety.

Sampling:--Look for wilted plants or masses of coarse excrement, especially on the stem near the ground level, which the borer has pushed out of the plant.

Count the number of wilted plants/10-25 examined.

Check 10-25 plants for borer tunnels. Record the number of tunnels and dissect for total larval counts. Carruth and Howe (1948) counted all plants in a given treatment and determined the percent infested with borers.

Take yield records. Record total number of fruits harvested and average number and weight of fruit/plant. Records may be taken from the entire plot or representative section therefrom.

Pickleworm, *Diaphania nitidalis* (Stoll) and Melonworm, *Diaphania hyalinata* (Linnaeus)

These insects are similar and can be evaluated by essentially the same techniques. There are some differences, however.

Fruits of muskmelon, cucumber and squash are severely injured by the pickleworm, *Diaphania nitidalis* (Stoll), watermelon rarely and pumpkin not at all. Earlier in the season the stems, terminal buds and blossoms are attacked. The melonworm, *Diaphania hyalinata* (Linnaeus), on the other hand, rarely enters the vine or leaf petioles but feeds extensively on the leaves. Unlike the pickleworm, the melonworm attacks pumpkin.

Brett and Sullivan (1970) have found considerable variation in the relative susceptibility of cucurbit varieties to pickleworm injury. When choosing a test variety, try to select one that is favored by pickleworms.

Unless foliage injury is severe, treat about 1 week before fruit set and make weekly applications thereafter.

Sampling:--Counts of infested fruit are reliable (Canerday 1967). Check 10-25 fruit or more/plot and record the number infested. If time permits, dissect for actual worm count. Frequent checks may be necessary since infested fruit will rot and disappear in short order.

Familiarize yourself thoroughly with the different types of foliage injury and record in as many ways as possible: infested stems, terminal buds or blossoms/10-25 plants/plot in the case of the pickleworm. Check foliage of 10-25 plants/plot for melonworms.

Take yields. Count damaged and undamaged fruit: record the weight of marketable fruit and average weight. Records may be taken from the entire plot or representative section therefrom.

Melon Aphid *(Aphis gossypii* Glover)

Symptoms in the field first appear as the edges of cucurbit leaves begin to curl downward with some of them wilted, shriveled, and brown. Like other species of aphids, the melon aphid, *Aphis gossypii* Glover, sucks the sap from the plants causing reduced yields of poor quality. They also transmit cucumber mosaic virus.

In most test areas, aphids appear in conjunction with tests aimed at other insects. Occasionally, however, control investigations are started after an aphid outbreak or as a matter of routine infestation.

Sampling:--Make direct counts of total number of aphids/10-25 leaves/plot, selected from different plants.

Evaluate plant condition through a foliage or tip injury rating code.

Take yields. Record number and average size of fruit. If some fruit is unmarketable, determine the number and percent. Records may be taken from the entire plot or representative section therefrom.

Cabbage Looper *(Trichoplusia ni* (Hubner))

This cabbage looper, *Trichoplusia ni* (Hubner), has expanded its host range to a remarkable extent in recent years, especially in the middle Atlantic and southeastern states. Cucurbits, cucumbers in particular, have been hard hit and the looper is now regarded as a major pest of these crops in Virginia and bordering states.

Published references concerning looper control on cucurbits appear to be virtually non-existent. However, the same record taking techniques listed under the Crucifers are generally applicable for this group also.

Sampling:--After each application, evaluate the results by selecting 10-25 plants or leaves/plot (dependent on the infestation level) and count all the loopers. Divide loopers into size classifications similar to that used by Hale and Shorey (1972).

Take yield records. Records may be taken from the entire plot or representative section therefrom.

Mites *(Tetranychus spp)*

In hot, dry years several species of mites that occur in different regions often cause rather severe injury to cucurbits. Injury takes the form of a yellowish, chlorotic effect on the leaves and results in greatly reduced vigor and yield. As in the case of the cabbage looper, there seems to be little in the way of published references concerning mite control on cucurbits.

Sampling:--Make direct counts on the number of mites per 10-25 leaves/plot. If populations are too high, excise 3.22 cm^2 (0.5 $in.^2$) or 6.44 cm^2 (1.0 $in.^2$) leaf samples and count the mites thereon. These may be supplemented with visual ratings of plant vigor.

Take yields, record the total number and average weight of marketable and unmarketable fruit. Records may be taken from the entire plot or representative section therefrom.

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IRISH POTATOES

Irish potatoes, *Solanum tuberosum*, are one of the basic food crops in the world. In addition, they support a wide variety of insect pests, some of which occur in all areas where potatoes are produced.

Colorado Potato Beetle, *Leptinotarsa decemlineata* (Say)

The Colorado potato beetle, *Leptinotarsa decemlineata* (Say), is well known to practically everyone. After almost having been eliminated as a potato pest during the 1950's, this native species has increased to such an extent that it is the limiting factor in Irish potato production in New York, Virginia and other eastern and southeastern states. Due to its importance, in this outline we will emphasize suggested practices for this pest, with the view in mind that other insects and injury may be sampled and recorded using the same basic test structures. Both foliage sprays and systemic granulars applied to the soil should be evaluated.

Crop and Location of Tests:--Select a variety or varieties of Irish potatoes commonly grown in the area in question. Since some potato varieties respond differently to insecticidal treatments, especially the soil systemics (Getzin and Chapman 1959, Hoyman 1969, Libby 1971), it is highly desirable to observe as many varieties as possible. A uniform soil for the test area is desirable since the degree of control of plant response may vary in different soil types.

Experimental Design:--

Ground Application-A randomized complete-block design with three or more replications per treatment is suggested. Ideally, candidate insecticide performance should be compared with untreated plots and one or more standard insecticides recommended for the area in question. However, if it is impossible to have untreated controls, it should be sufficient to compare the treatments with one or more recommended standards.

Plot size may vary greatly, depending on the uniformity of infestation and population density. Hofmaster and Waterfield (1972a) obtained good results with plots 3, 5, or 10 rows wide by 10.7 m (35 ft.) long with 3-5 untreated rows between plots. Subsequent unpublished investigations by these workers have shown that 3 row plots, 10.7 m (35 ft.) long with 1 or 2 untreated rows between plots are about the smallest units that should be used for evaluation of soil systemics. For "screening" purposes utilizing foliage sprays, single 7.6 m (25 ft.) long plots with adjacent untreated rows have shown to advantage. However, as the compounds are taken beyond the screening stage, a 3, 4, 5, or 10 row plot size is recommended. Shands et al. (1972) employed 4 rows 7.6 m (25 ft.) long, Pond (1967) - 4 rows 11 m (36 ft.) long, Powell and Mondor (1973)

4 rows 30.5 m (100 ft.) long while Bacon et al. (1973) utilized plots 36 rows wide x 30.5 m (100 ft.) long.

Aerial Application-A minimum of 2 and preferably 3 swaths each 12.2 m (40 ft. wide) or covering a comparable area is suggested to prevent drift and have sufficient area in the middle of the plot to collect representative samples. The length should be sufficient to enable the pilot to fly level and safely over the plots for at least 182.6 m (600 ft.).

Application and Equipment:--Both spray and granular applications should be utilized in investigating Irish potato insect control and can be adapted to most of the species concerned.

Ground Application-Knapsack sprayers operating at 2.1 - 4.2 kg/cm^2 (30-60 psi) and delivering 187.1-935.4 liters/ha (20-100 gallons of water/ acre) will give satisfactory results. Calibrate the sprayers carefully and apply the spray along each side of the row and over the top. Where single nozzles are used this will require a trip along each side and back over the top. Backpack sprayers may have a spray boom equipped with 3 nozzles per row. These nozzles should be adjusted so as to cover the top and sides of each row (Hofmaster and Waterfield 1972b).

In moving to larger plots a wide variety of pressures and rates are encountered, e.g., Powell and Mondor (1973) with 187.1 liters/ha (20 gallons/ acre) at low pressure and Pond (1967) 935.4-1169.2 liters/ha (100-125 gallons/ acre) at 28.1 kg/cm^2 (400 psi). Insofar as possible, all testing on larger plots should be with equipment that is adaptable to the area in question.

Granules may best be applied with a commercial granular applicator attached to the potato planter. Calibrate the applicator for each formulation and rate and then plant the potatoes directly without resetting. Many methods of granule placement are possible. Hofmaster and Waterfield (1972a) studied 8 different methods and concluded that placing the granules directly in the fertilizer band on both sides of the row gave best results. If the fertilizer will be broadcast, place the granules about 10 cm (4 in.) from the seed-piece and about 2.54 cm (1 in.) below the seed-piece level. Some areas such as New York favor placing the granules directly in the furrow so this method should be compared to banding.

Aerial Application-Use nozzle arrangement and volume of finished spray determined to be practical under existing conditions. In most areas the spray volume will range from 18.7-93.5 liters/ha (2-10 gallons/acre) although good insect control has been obtained with lower or higher dosages.

Regardless of the method of application, the equipment should be thoroughly cleaned before each use. When changing treatments, the tank, boom and nozzles should be rinsed with water run through the entire system until it is clear.

If more than one rate (kg/ha or lbs/acre) of toxicant is used, start the test sequences with the lowest rate, thereby keeping the chances of contamination at a minimum. Generally, several rates should be applied when testing is in the initial phase. After the rate or rate range is established and testing is in the final stages, emphasis should be placed on the probable rate or rates to be used.

Sampling:--Direct counts of Colorado potato beetle egg masses and larvae with supporting measurements of adult foliage injury, either by estimates of defoliation or the actual number of plants defoliated, give a comprehensive picture of performance against this pest (Hofmaster and Waterfield 1972a).

Early adult feeding to differentiate effectiveness of soil systemics- Some systemics become active 7-10 days after plants emerge while others are effective almost at time of emergence.

1. Number of plants "stemmed" (clipped at ground level by adults feeding) 5-7 days after plant emergence.
2. Number of plants with noticeable foliage injury. Rating of degree thereof, if feasible.
3. Number of egg masses/10 plants may give some interesting supporting data.

Effectiveness against potato beetle larvae-

1. Number of larvae/10-25 plants or more. Indicate approximate larval instars. Record data at definite intervals such as 5, 24, 48, and 72 hours and 7 and 14 days in order to get idea of knockdown and residual. The intervals selected may be at the discretion of the observer; depending on time available and need for additional data.

   If populations are low, plants can be artificially infested with known numbers of larvae from the same general area.
2. Some insecticides are slow in action and treated larvae may enter the soil before dying. Count adult emergence holes/10 samples of 0.093 sq. meters (1 sq. ft.).

Effectiveness against spring generation adults-

1. Recently emerged adults move about too much for direct counts, unless the plots are quite large. Numerical foliage injury ratings such as 1 to 5 (Hofmaster and Waterfield 1972) may be used to advantage.

   Take tuber yields and specific gravities. Evaluate potatoes according to U.S. #1 and U.S. #2 grades. Check on unusual effects of chemicals such as sprouting, knobs, etc. Yields may be from entire plots or representative sections therefrom; convert to kg/ha or cwt/acre.

Analysis and Reporting of Data:--Compare treatment means using a valid statistical method such as Duncan's multiple-range test. Candidate insecticide performance should be compared with replicated untreated plots and one or more standard insecticides recommended for the area in question. Where it is impossible to leave untreated areas, comparison with one or more standard insecticides should suffice.

The following data should be reported:

1. Pre-test counts to determine approximate level of the insect population prior to treatment. This may not be possible for all types of insects.
2. Insecticide formulation used and kilograms active toxicant/hectare or lbs. active/acre. Describe application equipment, quantity delivered, pressure, etc.
3. Insect populations on given date, stage of plant growth, and listing of sampling technique.

4. Plant height, stage, and condition at time of treatment and sampling.
5. Temperature, humidity, rainfall and general weather conditions at treatment. Record these for all applications and all except humidity for the sampling dates. Overall weather records for the entire test period may be useful.
6. Percent organic matter and type of soil.
7. Plant response, phytotoxicity or obvious defects in the harvested crop.

Potato Flea Beetle, *Epitrix cucumeris* (Harris)

Follow the same general experimental technique as described for the Colorado potato beetle. The only variations will be in sampling.

Sampling:--Potato flea beetles, *Epitrix cucumeris* (Harris) move around so much that sampling them is difficult. Sweeping is not reliable due to variations in technique and nature of the potato plant.

Count the feeding scars on five leaves/plant, two low down, two near the middle and one from the top of five or more plants selected at random from each plot. If the numbers are too large to count, excise definite areas such as 3.22 cm^2 (0.5 $in.^2$) or 6.44 cm^2 (1.0 $in.^2$) with a cork borer or other suitable means and count the scars thereon. (Hofmaster et al. 1967.)

In some areas, two meaningful foliage injury counts may be taken; overwintered beetles, and first brood adults. In Virginia these would be approximately 5-6 weeks apart. Start insecticide applications in both cases as soon as the beetles appear.

Flea beetle larvae work into the soil and feed on rootlets and tubers. Injury to the tubers consists of small holes with corky slivers or elongated winding scars. Count the number of scars on at least 20 tubers or section thereof, if the injury is heavy. (Hofmaster et al. 1967.)

Take tuber yields and specific gravities. Yields may be from the entire plot or representative areas therefrom: convert to kg/ha or 100 cwt/acre. Evaluate according to U.S. #1 or U.S. #2 grades.

Potato Leafhopper, *Empoasca fabae* Harris, and Other Leafhoppers

Follow the same general technique as for the Colorado potato beetle. The only variations will be in sampling.

Sampling:--

Adults-Check for presence of adult leafhoppers by sweeping but do not make counts this way. The adults are so agile that attempts to count them accurately are not generally practical.

Nymphs-

1. Apply regular treatment schedule and evaluate by counting the nymphs on the underside of the leaves (Hofmaster et al. 1967). Select at least 50 leaves/plot.

2. Make visual numerical ratings for development of "hopperburn" injury by the potato leafhopper, *Empoasca fabae* Harris, and southern garden leafhopper, *Empoasca solana* DeLong, also the speckled white-stippled appearance by the western potato leafhopper, *Empoasca abrupta* DeLong. Record the extent of purple-top wilt infection by the aster leafhopper, *Macrosteles fascifrons* (Stal) and of curly top virus infection by the beet leafhopper, *Circulifer tenellus* (Baker).

Count the number of injured or infected plants/given unit or plot and possibly grade injuries such as "hopperburn", purple-top wilt, etc. Check while plants are actively growing at blossom time.

Observe the tubers for obvious disease. (If facilities are available, it might be desirable to store seed and check for disease development when planted later, either in the greenhouse or field.)

Take yields and specific gravities: yields may be from the entire plot or representative sections therefrom; convert to kg/ha or cwt/acre. Evaluate according to U.S. #1 or U.S. #2 grades.

European Corn Borer, *Ostrinia nubilalis* (Hubner)

Irish potatoes are the principal spring host plant of the European corn borer in Virginia and other Atlantic seaboard states. In addition, the fall crop is also attacked.

Foliage treatments must be preventive by nature. Two criteria may be used for initiating the spray program: 1) Consistent moth flights as determined by light trap collections; and 2) Appearance of egg masses in the field. Successful tests against this pest require a thorough knowledge of the life history and cultural practices in the area in question. Applications should be on an approximate 7 day schedule, and must be started before the borers have entered the plants.

Soil systemics should also be evaluated, especially new chemicals. These must be applied at planting.

Sampling:--Corn borer infestations are self evident as the plants either break over or wilt and die. Usually only one field count will be necessary but this will entail dissection of at least 5 plants/plot - preferably 10 or more plants.

Insect data may be taken in several forms: 1) Number of plants injured by corn borers; or 2) Number of borers/plant or plants. (Hofmaster et al. 1967.)

Supporting data should consist of yields and specific gravities. Evaluate as U.S. #1 or U.S. #2 grade. Yields may be taken from entire plots or representative sections therefrom; convert to kg/ha or cwt/acre. Note possible secondary effects from corn borers on the tubers, such as stem-end discoloration, reduced size, etc.

Potato Psyllid, *Paratrioza cockerelli* (Sulc)

These small insects are often called jumping plant lice and are problems in the western states. The feeding of potato psyllid nymphs causes a disease known as psyllid yellows. This is characterized by a change in color from green to light yellow and upward curling of the leaves over the midrib. In advanced stages the plant appears to consist principally of primary stems. The set of tubers is substantially increased but they never reach marketable size; aerial tubers also form in the leaf axils.

Sampling:--Start treatments when one or more adult psyllids can be caught in 100 sweeps of a standard sweep net, with the net opening hitting 2/3 below the top of the plants (one adult psyllid/100 sweeps may reduce yields as much as 10 bushels per acre). If the psyllid populations are not determined, start insecticide applications when the plants are 6 inches tall (U.S. Agric. Handbook 264: Potato Insects: Their Biology and Control, pages 40-41).

Make counts of the number of psyllid nymphs on at least 25 leaves/plot. (Gerhardt 1966.)

Check for development of psyllid yellows. Record the number of plants obviously infected and group in an acceptable rating class to differentiate the degree of injury.

Take yields and specific gravities. Grade potatoes carefully into U.S. #1 and U.S. #2 classes: check size average. Yields may be taken from entire plot or representative sections therefrom, convert to kg/ha or cwt/acre.

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Aphids

The following test methodology to determine the efficacy of insecticides to control aphids on potatoes is very similar to the method previously described under Cruciferae and Head Lettuce - Aphids and Thrips. Only the modifications of that method are noted below.

Crop and Location of Tests:--See also Aphids and Thrips - Cruciferae and Head Lettuce.

In the early stages of testing, plots 3 beds wide by 7.6 m (25 ft.) long should be large enough if the counts are made from the middle row of each plot.

Sampling:--Count the total number of apterous aphids on 50-75 leaves per plot. The number of leaves selected would depend upon the intensity of the infestation. It is suggested that the leaves be selected at random from the middle area of the plot. Care should be taken to keep within a well buffered zone.

Small screening hand plots that are 3 beds wide by 7.6 m (25 ft.) should have an observation area one bed wide and 1.5 m (5 ft.) from the end of each plot. This method would provide a 2 bed buffer zone on each side of each plot.

Ground plots that are 12-16 beds wide by 18.3 m (60 ft.) long should have an observation area 4-6 beds wide and at least 4.6 m (15 ft.) away from the end of each plot. This method would provide an 8-10 bed buffer zone on each side of each plot.

Air plots that are 36.6 m (120 ft.) wide by 182.9 m (600 ft.) long should have an observation area 12.2 m (40 ft.) wide and 30.5-45.7 m (100-150 ft.) away from the end of each plot. This method would provide a 24.4 m (80 ft.) buffer zone on each side of each plot.

References

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Potato Tuberworm, *Gnorimoschema operculella* (Zeller)

The following test methodology to determine the efficacy of insecticides to control potato tuberworms is very similar to the method previously described under Cruciferae and Head Lettuce - Aphids and Thrips. Only the modifications of that method are noted below.

Crop and Location of Tests:--In the early stages of pesticide testing, small plots with ground applications would suffice to demonstrate efficacy if the width and length of the plots were large enough to prevent drift of applied materials to adjacent plots: and large enough to sample tubers without drift from adjoining plots influencing the sampling area.

For the very early tests that involve "screening" only, plots can be 3 beds wide by 7.6 m (25 ft.) long. However, as the compounds are tested past the initial screening stage, larger plots are recommended. Plots 12-18 beds wide by 18.3 m (60 ft.) long should be large enough to prevent the normal movement of adult moths from unduly influencing the results between plots under normal tuberworm pressure.

In the final stages of pesticide development the plot size should be larger to more closely resemble the commercial ground and air applications. But in any event should be large enough to prevent drift from adjacent plots from influencing the results. Since most commercial ground applicators treat 6-8 beds per swath, plots should be 18-24 beds wide by 60.9 m (200 ft.) long. The length to be long enough to harvest a representative sample of tubers. Air plots should be 36.6 m (120 ft.) wide or 3 swaths of 12.2 m (40 ft.) in width to prevent drift and to have enough area in the middle of the plot to harvest a representative sample of tubers. The length to be long enough to enable the pilot to fly level and safely over the plots for at least 182.9 m (600 ft.).

Application and Equipment:--A broadcast boom with flat fan tips (8004 is suggested) arranged equidistant should provide optimum coverage when using ground equipment. When small screening tests are applied, knapsack sprayers operating at 2.1-4.2 kg/cm^2 (30-60 psi) will give satisfactory results. The boom should have 3- flat fan nozzels per row. Air application equipment should be commercially acceptable.

The finished spray volume per acre would be dependent on the size of the potato plants. When foliar spray is applied by small hand or large ground equipment, 227.1-378.5 liters/ha (60-100 gallons/acre) will give satisfactory results. When foliar spray is applied by air, 37.9-56.8 liters/ha (10-15 gallons/acre) will give satisfactory results.

The time of application should be when the rows start to close (leaves from adjoining beds touching across furrow). (Note: there is testing presently being conducted to ascertain whether earlier pesticide applications are feasible when "Monitoring" traps show moth activity.)

Since the control of tuberworms require preventive type treatments, the spray should be applied every 10-14 days until harvest, making sure to observe the waiting period from the last application to the harvest when using registered standard materials. The number of days interval is dependent on the area in which the testing is being conducted. When feasible more than one time interval between treatments should be evaluated.

Sampling:--Normal harvest procedures for the area in which the test is being conducted should be followed.

Select harvested tubers at random over a wide area of the plot so that a representative sample can be taken, but at all times keeping within a well buffered zone.

Small screening hand plots that are three beds wide by 7.6 m (25 ft.) long should have a tuber selection area one bed wide and 1.5 m (5 ft.) from the end of each plot. This method would provide a 2 bed buffer zone on each side of each plot.

Ground plots that are 12-24 beds wide by 18.3 m-60.9 m (60-200 ft.) long should have a tuber selection area 4-8 beds wide (middle one-third) and at least 4.6 m (15 ft.) away from the end of each plot. This method would provide a 8-16 bed buffer zone on each side of each plot.

Air plots that are 36.6 m (120 ft.) wide by 182.9 m (600 ft.) long should have a tuber selection area 12.2 m (40 ft.) wide (middle one-third) and 30.5-45.7 m (100-150 ft.) away from the end of each plot. This method would provide a 24.4 m (80 ft.) buffer zone on each side of each plot.

The total number of tubers selected for examination per each pesticide tested, regardless of the total number of plots, should be 500-600 tubers. This would give a wider range of selectivity and provide a better reading of the tuberworm damage.

Each tuber should be examined and recorded as damaged if a tuberworm mine is found. Extreme care should be taken to be sure that the mine is made by the tuberworm. Normally one mine is enough to grade the tuber down or discard it as a "cull", so normally the number of mines per tuber are not significant enough to record unless "severity of infestation" type data is requested.

The total number of tubers infested is recorded as well as the percent tubers infested. Care should also be taken to separate "Green tubers" (those that are exposed or on the surface) from the "Marketable" tubers when recording those that are infested.

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LETTUCE

European Lettuce Root Aphid, *Pemphigus bursarius* (L.)

The following test methodology to determine the efficacy of insecticides to control European lettuce root aphids on lettuce is very similar to the method previously described under Cruciferae and Head Lettuce - Aphids and Thrips. Only the modifications of that method are noted below.

Crop and Location of Tests:--See also Aphids and Thrips - Cruciferae and Head Lettuce.

For the very early tests that involve "screening" only, plots can be 2 beds (4 rows) wide by 7.6 m (25 ft.) long. However, as the compounds are tested past the initial screening stage, larger plots are recommended. Plots 4 beds (8 rows) wide by 15.2 m (50 ft.) long should be large enough to provide adequate space in the treated area.

In the final stages of pesticide development the plot size should be larger to more closely resemble the commercial ground applications, but in any event should be large enough to prevent drift from adjacent plots from influencing the results. Since most commercial ground applicators treat 6-8 beds per swath, plots should be 6-8 beds wide by 30.5 m (100 ft.) long. The length to be long enough to be able to randomly select and sample lettuce root systems to determine the degree of infestation and extent of damage to the plants.

Application and Equipment:--If granular materials are used, then the hoppers, tubes and shoes or shanks should be emptied and inspected to see that no material clings or plugs any part of the equipment.

A broadcast boom with flat fan tips (8004 is suggested) arranged equidistant should provide optimum coverage when using ground equipment. For a granular application, equipment that meters out small amounts such as the Gandy, Gustafeson, etc., and is capable of dispensing the correct amounts to be applied through shanks should be used.

The time of application should be just before the first irrigation following thinning of the lettuce.

One application of spray (broadcast) or granular application should be sufficient if the material has capabilities of controlling the lettuce root aphid. Granular applications tend to provide more effective and longer control.

For additional information, see Aphids and Thrips - Cruciferae and Head Lettuce.

Sampling:--Normal harvest procedures for the area in which the test is being conducted should be followed.

Select lettuce plants to be inspected at random over a wide area of the plot so that a representative sample can be taken, but at all times keeping within a well buffered zone.

Small screening hand plots that are 2 beds (4 rows) wide by 7.6 m (25 ft.) long should have a plant selection area from the middle two rows (inside row of each bed), and 1.5 m (5 ft.) from the end of each plot.

Ground plots that are 4-8 beds (8-16 rows) by 15.2-30.5 m (50-100 ft.) should have a plant selection area from the middle rows and 4.6 m (15 ft.) from the end of each plot.

The total number of lettuce plants inspected for each plot should be at least 25. If 50 plants can be inspected this would give a wider range of selectivity and provide a better reading of the lettuce root aphid infestation and damage.

Each plant should be given a rating for general appearances. The method is immaterial as long as the rating scale is consistent and is used only to show any differences in the plant on the surface that may be caused by the root aphid below the surface.

Each plant should be dug and the root system and surrounding soil area inspected for presence of the lettuce root aphid.

To determine the degree of infestation, it is suggested that a count be taken, for a given period of time (2-3 min.) by 2 or 3 investigators, of the number of aphids present on roots and in the soil.

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LIMA BEANS

Lygus Bug, *Lygus* spp.

The following test methodology to determine the efficacy of insecticides to control lygus bugs on lima beans is very similar to the method previously described under Cruciferae and Head Lettuce - Aphids and Thrips. Only the modifications of that method are noted below.

Crop and Location of Tests:--Small hand plots are not very practical because of the mobility of the adult lygus bugs. Plots 12-18 beds wide by 18.3 m (60 ft.) long should be large enough to prevent the normal movement of adult lygus from unduly influencing the results between plots under normal lygus pressure.

Since most commercial ground applicators treat 6-8 beds per swath, plots to test commercial ground applicators should be 18-24 beds wide by 30.5 m (100 ft.) long. The length must be long enough to harvest a representative sample of bean pods.

Application and Equipment:--A broadcast boom with flat fan tips (#8002-8004 is suggested) arranged equidistant should provide optimum coverage when using ground equipment. Air application equipment should be commercially acceptable.

When foliar spray is applied by ground equipment, a finished spray volume of 227.1-378.5 liters/ha (60-100 gals./acre) will give satisfactory results.

When foliar spray is applied by air, 37.9-56.8 liters/ha (10-15 gals./acre) will give satisfactory results.

The most critical time for the initial treatment is when the beans are in the early blossom and bud stage and when the lygus population is 1 nymph or adult per sweep. This method protects the young blossoms and buds and consequently increases production of pods. A sweep is one complete pass across one bed (2 rows). Fifteen sweeps per area is recommended.

The time interval from the initial application to the second treatment is based on the number of lygus (nymphs and adults) per sweep. This method protects the developing pods and maturing beans.

One to three days is suggested as the initial interval between treatment and observations and then every 7 days thereafter until control is no longer considered economic.

Sampling:--Count the total number of lygus nymphs and adults from 30 sweeps per plot. Make the sweeps across one bed (2 rows). One complete pass equals one sweep. Be sure that the sweeps are made from the middle area of the plot.

To evaluate the effect of lygus control to injury of the mature lima beans, normal harvest procedures for the area in which the test is being conducted should be followed.

Select harvested beans at random over a wide area of the plot so that a representative sample can be taken, but at all times keeping within a well buffered zone. The beans can be selected directly from the bin on the harvester. Select approximately 10-20 lbs. of harvested beans from each plot. From this sample take 5-10 cups and examine each bean from each cup for lygus injury and record as damaged. The total number of beans from this sample is counted so that the percent lygus injury can be recorded.

All beans in a given area of the central part of the plot should be harvested. Marketable beans should be weighed and the data converted to kg yield per hectare (lbs. yield per acre).

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PEAS

Pea Aphid

The pea aphid, *Acyrthosiphon (=Macrosiphum) pisi* (Harris), is the most serious pest of canning and dried peas throughout the pea- and alfalfa-growing districts of the United States and Canada. Overwintering as eggs or as viviparous females on alfalfa, clovers and other perennial legumes, where it builds up large colonies in early spring, winged migrants appear on young pea plants in early May. Reproduction is rapid and colonies develop on terminal shoots causing leaf distortion and death of the tips. Young pea plants are killed outright, and yield of older plants is reduced or the quality of peas is affected. This aphid is also an important vector of pea enation mosaic virus, also of bean yellow mosaic of peas and alfalfa. Most commercial growers must be prepared to treat their pea fields and suppress this insect sufficiently to prevent partial or complete losses of their crop (Metcalf et al. 1962).

Crop and Location of Tests:--Select a variety or varieties of peas commonly grown in the same geographical area. Locate test plots near alfalfa or other overwintering hosts for the pea aphid to increase intensity and uniformity of infestation in peas.

Soil type should be specified if systemics are being tested (Specht and Chisholm 1970). Regional or climatic differences may influence efficiency of the test chemical so test plots should be located in the various regions in which peas are grown (Kumar and Rabinder 1973).

Experimental Design:--A randomized complete block design with four or more replicates per treatment is suggested. Plot size may vary greatly depending upon the anticipated uniformity of infestation and population density, also the type of equipment and insecticide formulation being used.

In-furrow treatments with systemic insecticides were made in 3- to 6-row plots that were a minimum 7 m (20 ft.) long (Cook et al. 1963). Systemics in foliar sprays were applied to peas in rows with compressed air sprayers (Apple and Martin 1955). Anderson and Brooks (1947) employed 5-row plots up to 65 m (200 ft.) long for ground equipment with dusts, sprays, and aerosols; and for aircraft application their plots were 1 ha (2.47 acres) or larger.

Application and Equipment:--Systemics are applied to the seed before planting as granules in the furrow with the seed or as sprays to the foliage (Bronson and Dudley 1951). Dusts and low volume sprays are applied by ground equipment or aircraft (Anderson and Brooks 1947).

Sampling:--Sampling methods may vary according to the type of experiment and condition of the crop.

Cook et al. (1963) estimated the number of living aphids on each of 20-25 randomly located pea plants in each plot and grouped them into 10 categories from 0 aphids to more than 400.

Anderson and Brooks (1947), and Apple and Martin (1955) sampled populations by jarring aphids into a pan placed beside the row of plants.

Anderson and Brooks (1947), Davich and Apple (1951), and others used standard size sweep nets and a prescribed number of strokes for collecting aphids from plo[illegible]. The aphids were either counted or measured and the numbers estimated.

Pretreatment samplings should be made. Samples are usually taken 1 day posttreatment and again 7 and 14 days (Davich and Apple 1951; Bronson and Dudley 1931).

Take yield data including weight and quality of shelled peas, and weight of vines.

Analysis and Reporting of Data:--Compare treatment means using a valid statistical method such as Duncan's Multiple Range Test. Candidate insecticide performance should be compared with replicated untreated plots and one or more standard insecticides recommended for the area.

The following data should be reported:

1. Make pretreatment counts to determine the approximate level of the population prior to treatment.
2. Insecticide formulation used and kilograms active ingredient/hectare (lbs. a.i./acre). Describe application equipment, quantity delivered, pressure, etc.
3. Insect populations and stage of development on a given date, listing sampling technique.
4. Plant height, stage and condition at time of treatment and sampling.
5. Temperature, humidity, rainfall and general weather conditions at treatment. Record these for all application dates and all except humidity for the sampling dates. Overall weather records for the entire period may be useful.
6. Percent organic matter and type of soil, also soil temperatures where systemics are being tested.
7. Plant response, phytotoxicity or obvious defects in the harvested crop.
8. Yield of harvested peas and of vines.

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Pea Weevil

The pea weevil, *Bruchus pisorum* (Linne), attacks peas throughout the country. There is only one generation per year and the winter is passed in the adult stage; in the south, the adults leave the seeds in the fall and hibernate in protected places but, in the north, they remain in the seeds that are left in the field or in untreated seed that is planted. Adults feed on foliage and pollen of pea plants and lay their eggs on the pods. Hatching larvae bore into the pods and each one enters a separate seed. Infested green peas at harvest have a dot-line entrance hole which is generally overlooked and the peas are eaten. This pea weevil never lays eggs on dry peas, and the adults must get to the growing plants in the spring or perish without laying eggs.

Crop and Location of Tests:--Since the pea weevil is most serious in the dry pea or seed growing areas of the intermountain areas, test plots of peas should be located in Idaho or neighboring states. Also, establish test plots in other areas where this insect is a serious economic problem, especially where adults come to pea fields from hibernating quarters.

Experimental Design:--A randomized complete block design with four or more replicates per treatment is suggested.

Plot size of 0.0405 hectare (0.1 acre) is suggested (Brindley et al. 1948), but plot size may vary depending upon the anticipated uniformity of infestation and population density.

The experiment should include an untreated control and one or more standard treatments for comparison with test compounds.

Application and Equipment:--Make one application of dust or spray formulations to the foliage of peas during the period of early bloom and before the adults lay their eggs on the young pods.

Adapt the equipment at hand which is being used for control of pea aphids.

To test systemics against the pea weevil, follow the same procedures as outlined for tests against pea aphids.

Sampling:--Select 50-100 pea pods at harvest from each plot and observe for adult emergence from the dry peas in late summer. Samples can be held in screened containers to allow normal drying and maturity of peas and yet retain emerging weevils. Since only one weevil develops per pea seed, the effectiveness of test material is readily determined.

Analysis and Reporting of Data:--See this section under Pea Aphid.

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PEPPERS, *Capsicum annuum*

European Corn Borer, *Ostrinia nubilalis* (Hubner)

The European corn borer, *Ostrinia nubilalis* (Hubner), is a limiting factor in pepper production in the mid-west, mid-Atlantic states and southeastern states. Detection is especially difficult since the young borers enter the fruit under the cap and leave little external evidence. Due to its extreme importance in certain areas, suggested practices for this pest will be emphasized. Other insects and injury may be sampled and recorded, using essentially these same test methods. Both foliage sprays and systemic granulars applied to the soil should be evaluated.

Crop and Location of Tests:--Select the variety or varieties commonly grown in the same geographic area.

Experimental Design:--

Ground Application-A randomized complete block design with three or more replications per treatment is suggested. Ideally, candidate insecticide performance should be compared with one or more standard insecticides recommended for the area in question. However, if it is impossible to have untreated controls, it should be sufficient to compare the treatments with one or more recommended standards.

Plot size may vary greatly, depending on the anticipated uniformity of infestation and population density. Hofmaster et al. (1960) used 3 row plots 15.2 m (50 ft.) long with 2 untreated rows between each plot. Later unpublished data showed that single 15.2 m (50 ft.) rows with 1 adjacent untreated row gave consistent results. Tysowsky (1969) obtained good results by treating single 24.4 m (80 ft.) long plots bordered by untreated rows. Burbutis et al. (1960 and 1963) and Ryder et al. (1969) conducted extensive field research on corn borer on peppers using plots ranging from 4 rows wide x 21.3 m (70 ft.) long to plots 122 m (400 ft.) long and 20 rows wide. Hale and Shorey (1971) worked with plots ranging from 6-12 rows wide and 18.3-45.7 m (60-150 ft.) long.

Aerial Application-A minimum of 2 and preferably 3 swaths each 12.2 m (40 ft.) wide or covering a comparable area is suggested to prevent drift and to have sufficient area in the middle of the plot to collect representative samples. The length should be sufficient to enable the pilot to fly level and safely over the plots for at least 182.6 m (600 ft.).

Application and Equipment:--Both liquid and granular applications should be considered in investigating pepper insect control and can be adapted to most of the species concerned.

Ground Application-Due to the nature of the pepper plant and difficulty in hitting the cap area, problems of coverage can occur with backpack sprayers although this method may be used to advantage in combating pests other than the corn borer.

Hofmaster et al. (1960) applied 935.4 liters of water/ha (100 gallons/acre) at 17.6 kg/cm^2 (250 psi) using 5 or 6 nozzles/row. Tysowsky (1969) also used a power sprayer in small plots, application was at 7.03 kg/cm^2 (100 psi) at 467.7 liters/ha (50 gallons/acre). Burbutis et al. (1960 and 1962) and Ryder et al. (1968) conducted extensive field scale tests with power equipment delivering 467.7-935.4 liters/ha (50-100 gallons/acre) with both high pressure and air blast sprayers. Hale and Shorey (1971) evaluated application methods against another pepper pest, the green peach aphid, and found nozzle arrangement to be important.

Granules are usually side-dressed in the fertilizer band after the peppers have been transplanted and are established. Commercial applicators may be used (Ryder et al. 1969) or hand application (Shorey 1963). In Delmarva, two applications, one at 2-4 weeks after transplanting and another 4-6 weeks later are recommended. Placement will be governed by plant size but 5.1-12.7 cm (2-5 in.) deep and 7.6-15.2 cm (3-6 in.) from the plant are suggested.

Aerial Application-Use nozzle arrangement and volume of finished spray determined to be practical under existing conditions. In most areas the spray volume will range from 18.7-93.5 liters/ha (2-10 gallons/acre) although good insect control has been obtained at lower or higher dosages.

Regardless of the method of application, the equipment should be thoroughly cleaned before each use. When changing treatments, the tank, boom and nozzles should be rinsed with water run through the entire system until it is clear.

If more than one rate (kg/ha or lbs/acre) of toxicant is used, start the test sequences with the lowest rate, thereby keeping the chances of contamination at a minimum. Generally, several rates should be applied when testing is in the initial phase. After the rate or rate range is established and testing is in the final stages, emphasis should be placed on the rate or rates to be submitted for registration.

Sampling:--Check and dissect, if necessary, 25-100 mature peppers/plot for corn borer injury. Be sure to look carefully under the cap area. If larger samples with uneven numbers are collected, obtain percent infestation and convert to arc sin ± for analysis. (Burbutis et al. 1960 and 1962, Hofmaster et al. 1960, Ryder et al. 1969). Since many fruits rot if infested with borers, keep a close check for "rots" and record these. Examine and remove "rots" as they appear.

Take yields, recording the marketable fruit, % loss due to borers and number of "rots". Yields may be from the entire plot or representative sections therefrom; convert to metric tons/ha or tons/acre.

Analysis and Reporting of Data:--See statement under Cabbage Looper - Cruciferae. (Obviously, in treatments of a precautionary type (corn borer) based on a preventive schedule, pre-test counts cannot be taken as such. However, light trap collections may provide helpful information.)

Green Peach Aphid (#1) *Myzus persicae* (Sulz.)

Yields may be seriously reduced by aphid feeding and the fruit made unsalable from a black fungus developing in aphid "honeydew" which dripped on the fruit. Follow the same general procedures as outlined for corn borers. The only differences will be in sampling.

Sampling:--Count the total number of aphids/10-100 leaves/plot or parts thereof, if the infestation is heavy. (Burbutis et al. 1960 and 1962, Hale and Shorey 1971, Hofmaster et al. 1960, Shorey 1961 and 1963.)

Harvest and record marketable fruit and peppers covered with black "honeydew" fungus. Yields may be taken from the entire plot or representative sections therefrom; convert to metric tons/ha or tons/acre.

Pepper Maggot, *Zonosemata electa* (Say)

The larvae of this Tephephritid fly feed entirely inside the pepper fruits. A single maggot makes the pepper worthless for marketing. This pest is unusual in that it is single brooded and the larvae pupate in the soil, with adults emerging the following year (Davidson and Peairs 1966).

Control demands a thorough knowledge of the biology. Check for the appearance of adults (two-winged, yellow striped flies about 0.76 cm (0.3 in.) long) and make regular treatments as long as the flies are around. In New Jersey treatments should start the last week of June and continue at 7 day intervals until July 15; treat every 10 days thereafter through July. Plots should be 4 rows wide by 15.2 m (50 ft.) long with at least 4 replications.

Sampling:--Check 50-100 fruit/plot for pepper maggot injury. Race and Reed of Rutgers University, New Brunswick, New Jersey, suggest the following method of evaluation (personal communication):

After the 3rd spray application (usually about mid-July in New Jersey) collect 50 peppers from the center rows of each plot; 25% of the collected peppers/plot should be the smallest size present in the field, ranging up to thumbnail size; 25% should be the largest size and the remaining 50% should be somewhere in between.

Check for egg punctures by examining the outside surfaces of all fruits. The egg puncture is easy to spot and is usually typified by a small dimple-like or depressed area. Experience can be gained very quickly in determining those fruits which have egg punctures and those which do not. Peppers with egg puncture marks should be opened carefully with a sharp blade. (It is not necessary to open those peppers which do not show the typical egg puncture scar.) Look for the tiny eggs on the inside surface of the fruit wall or presence of maggots feeding on the core. Full grown maggots obtain a length of approximately 6.4 cm (½ inch). Usually not more than 2 or 3 maggots occur in each pepper and often only one.

Record the number of fruit with egg punctures and total number of punctures. At the same time obtain the number of fruit infested with maggots and total number of maggots.

Take yields and estimate loss due to pepper maggot. Yields may be from the entire plot or representative sections therefrom; convert to metric tons/ha or tons/acre.

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Green Peach Aphid (#2) *Myzus persicae* (Sulz.)

The following test methodology to determine the efficacy of insecticides to control green peach aphids on peppers (bell or chili) is very similar to the method previously described under Cruciferae and Head Lettuce - Aphids and Thrips. Only the modifications of that method are noted below.

Crop and Location of Tests:--In early stages of testing, plots 3 beds wide by 7.6 m (25 ft.) long should be large enough if the counts are made from the middle row of each plot.

Since most commercial ground applicators treat 6-8 beds per swath, plots to test using commercial ground applicators can be 6-8 beds wide by 18.3 m (60 ft.) long.

Application and Equipment:--When the pepper plants are small enough so that a ground application can be safely made without knocking an excessive amount of blossoms and small pods from the plant, a row crop boom should be used for proper coverage.

Sampling:--Count the total number of apterous aphids on 50-75 leaves per plot. The number of leaves selected would be dependent on the intensity of the infestation. It is suggested that the leaves be selected at random from the upper one-third and the lower one-third of the plants. Care should be taken to keep within a well buffered zone in the middle area on the plot.

Small screening hand plots that are 3 beds wide by 7.6 m (25 ft.) long should have a leaf selection area one bed wide and 1.5 m (5 ft.) from the end of each plot. This method would provide a 2 bed buffer zone on each side of each plot.

Ground plots that are 6-8 beds wide by 18.3 m (60 ft.) long should have a leaf selection area 2-4 beds wide and at least 4.6 m (15 ft.) away from the end of each plot. This method would provide a 4 bed buffer zone on each side of each plot.

Air plots that are 36.6 m (120 ft.) wide by 182.9 m (600 ft.) long should have a leaf selection area 12.2 m (40 ft.) wide (middle one-third) and 30.5-45.7 m (100-150 ft.) away from the end of each plot. This method would provide an 24.4 m (80 ft.) buffer zone on each side of each plot.

References

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SNAP BEANS, LIMA BEANS AND SOUTHERN PEAS

The crops include snap bean - *Phaseolus vulgaris*, lima bean - *Phaseolus lunatus*, and cowpea or southern pea - *Vigna sinensis*. These beans are infested by a large number of insect pests both in the field and in storage.

Mexican Bean Beetle, *Epilachna varivestis* Mulsant

The Mexican bean beetle, *Epilachna varivestis* Mulsant, has received more research efforts and publicity than any other bean pest. Like so many imported pests, its spread was extremely rapid, especially after moving eastward across the Mississippi around 1920. Suggested test procedures for this insect will be emphasized. However, other insects and injury may be sampled and recorded employing the same or quite similar test methods. Both foliage sprays and systemic granulars should be evaluated.

The following test methodology to determine the efficacy of insecticides to control the Mexican bean beetle on beans is very similar to the method previously described under Cabbage Looper - Cruciferae. Only the modifications of that method are noted below.

Experimental Design:--Plot size may vary greatly, depending on the uniformity of infestation and population density. The following references to plot size are not limited to Mexican bean beetle investigations but include other bean pests.

Chalfant (1973) employed plots 15.2 m (50 ft.) long by 4-6 rows wide in southern pea studies in Georgia. Judge et al. (1973) used 2 row 18.3 m (60 ft.) long plots with 2 buffer rows while Webb et al. (1970) obtained good results with single 9.1 m (30 ft.) rows. Comments from a number of workers indicated that 3-6 row plots ranging from 9.1 m (30 ft.) to 22.9 m (75 ft.) in length should afford good test conditions for the entire bean insect complex. Where optimum stress is desired, single row 9.1 m (30 ft.) to 22.9 m (75 ft.) long plots with 1 or more buffer rows may be used to advantage.

Application and Equipment:--Specially adapted small plot sprayers such as the CO_2 sprayer used by Wolfenbarger and Schuster (1963) are helpful. Mechanized equipment (Chalfant 1973) in which a tractor drawn sprayer delivering 467.7 liters/ha (50 gallons/acre) at 3.5 kg/cm^2 (50 psi) with 3 nozzles/row, can be used in small plots to simulate field scale conditions.

Granules may be applied with a commercial granular applicator attached to the planter. Calibrate the applicator for each formulation and rate and then plant directly without resetting. Webb et al. (1970) used an Alan distributor in placing the granules 2.54 cm (1.0 inch) below the seeds in the furrow or 5.08 cm (2.0 inches) to the side of the beans. Judge et al. (1970)distributed the granules directly over the beans; whereas Fisher (1966) placed the granules in the fertilizer band. Ideally, the insecticides should be placed approximately 5.1 cm (2.0 inches) to the side of the beans and at this same depth. Whatever the placement decided upon, be sure to pinpoint the granular location as accurately as possible. Although many chemicals are phytotoxic when in direct contact with the seeds, it will be advisable to include a direct contact series.

Sampling:--Make direct counts of larvae, taking samples of 10-25 plants/plot. If populations are not too heavy, record all larvae on the plant; otherwise check the larvae on at least 25 leaves/plot. Judge et al. (1970) sampled 15 plants/plot. The pupae attach themselves directly to the leaves. Occasionally it is desirable to make pupal counts, providing the initial treatment was applied prior to pupation. A further check on insecticidal efficiency may be obtained by determining whether adults emerge from pupae present at the time of treatment.

Activity of the test insecticide against the adults should be determined by feeding injury ratings.

Take yield records - 2 or 3 harvests. Checks on pod quality and size may show unexpected differences. Records may be from entire plot or representative sections therefrom.

Bean Leaf Beetle, *Cerotoma trifurcata* (Forster)

Damage by bean leaf beetles, *Cerotoma trifurcata* (Forster), is two-fold. The adults feed on the underside of the leaves, eating rounded holes in them, while the larvae feed underground on the roots and stems, often girdling the plants.

Sampling:--

Adults-Make direct counts on 10-25 plants/plot. Supplement with counts of feeding holes/10-25 leaves/plot.

Larvae-Remove plants from the soil and examine roots for larval injury and/or larvae. Check 5-10 plants/plot at least one time.

Take yields from 2 or 3 harvests, either from the entire plot or representative sections therefrom.

Bean Aphid, *Aphis fabae* Scopoli

As is the case with most aphids, continuous feeding by the bean aphid, *Aphis fabae* Scopoli, causes the leaves to turn yellow, plants to become dwarfed and malformed with quality and yield reduced.

Sampling:--Dependent on populations, count all aphids on 10-25 leaves/plot or representative portions of 3.22 cm^2 (0.5 $in.^2$) or 6.44 cm^2 (1.0 $in.^2$) therefrom. Hagel (1970) found samples of 25 leaflets to be adequate.

Take yields from 2 or 3 harvests and record differences in size and quality of pods. Records may be from the entire plot or representative sections therefrom.

Cowpea Curculio, *Chalcodermus aeneus* Boheman

The curculio larvae feed within the developing seeds of various members of the bean family but prefer southern peas. Infestation usually occurs in the field where the female deposits eggs in feeding punctures as the southern peas begin to form. Pea pods infested with curculio can be recognized by small, brown, wart- or blister-like spots on the surface. These are either feeding punctures or areas present which may contain an egg or small grub. Make 3-5 treatments at 4-5 day intervals, beginning at blossoming.

Sampling:--Chalfant (1973) collected 50-100 pods/plot at 5-7 days after the last treatment. The pods were shelled and feeding and oviposition punctures (stings) on the green peas recorded. Other workers including Dupre and Beckham (1955) and Wolfenbarger and Schuster (1963) supplemented the above technique by collecting 50-100 pods at the developmental stage for processing, placing them in holding containers fitted in such a manner as to allow the larvae to fall to the bottom as they matured and left the peas.

Examine 50-100 pods/plot for stings, feeding punctures and damaged peas. Record the number of injured and uninjured pods and also the number of damaged peas and punctures/pod.

Place 50-100 pods/plot in holding cartons and check for larval emergence. Records should be taken of the total number of emerged larvae and damaged peas.

Take yield records and estimate loss due to the curculio. Records may be from the entire plot or representative sections therefrom.

Leafhoppers

Two species of leafhoppers, the potato leafhopper, *Empoasca fabae* (Harris), and beet leafhopper, *Circulifer tenellus* (Baker), cause extensive damage to beans.

The potato leafhopper causes dwarfed, crinkled and curled foliage, rosette formation, or small triangular brown areas at the tips of the leaves, gradually spreading around the entire margin. Affected plants produce few pods.

The beet leafhopper carries a virus disease known as "curly top" and is limited to the western areas. Beans in the seedling or crookneck stage are most susceptible to curly top and usually die when infected. However, plants infected when they are in a more advanced stage of growth often survive but produce stunted pods. Curly top is the most important factor limiting the growing of snap beans for seed in southcentral Idaho where the bulk of the nation's bean seed is produced. Unlike the potato leafhopper, the beet leafhopper does not reproduce on bean plants.

Sampling:--Count the number of potato leafhopper nymphs on 10-25 leaves/plot or, if the infestation is not heavy, on the entire plant. Judge et al. (1970) found counting all the nymphs on 15 plants to be practical. Supplement these counts with an evaluation of leafhopper damage to the foliage. Record plants with visible symptoms and grade according to severity.

Count the number of beet leafhopper adults/10-25 plants/plot. To do so will require a special sampling cage similar to the one developed by Hills (1933) and widely accepted by entomologists in the curly top areas. Supplement these counts with an evaluation of curly top damage. Make observations shortly after plant emergence and record plant stand since young plants may be killed. Check for stunted and distorted plants.

Make several harvests. Look closely for small, malformed pods and compare these with the number of apparently normal pods. Records may be taken from the entire plot or representative sections therefrom.

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SWEET CORN

Corn Earworm, *Heliothis zea* (Boddie)

The following test methodology to determine the efficacy of insecticides to control corn earworms on sweet corn is very similar to the method previously described under Cruciferae and Head Lettuce - Aphids and Thrips. Only the modifications of that method are noted below.

Crop and Location of Tests:--The plot size should depend on the stage of pesticide development. In the early stages, small hand applications would suffice to demonstrate efficacy, either as dusts or sprays. For the very early tests that involve "screening" only, plots can be 3 rows wide by 15.2 m (50 ft.) long.

In the final stages of pesticide development the plot size should be larger to more closely resemble the commercial ground applications. But in any event should be large enough to prevent drift from adjacent plots from influencing the results. Plots should be a minimum of 4 rows wide by 60.9 m (200 ft.) long.

Airplane applications are ineffective on moderate to heavy earworm populations which occur in most market sweetcorn-producing areas of the middle and southern parts of the U.S.A.

Application and Equipment:--Preliminary tests can be hand treatments either as dusts or sprays. Large scale field tests should be made with a high clearance spray rig, using 2-4 nozzles per row adjusted to cover only the ear area with particular attention to thorough coverage of the silks.

Satisfactory results can be obtained by applying a finished spray volume of 113.6-189.3 liters/ha (30-50 gals./acre). A moderately coarse spray with hollow cone nozzles provides good results.

The time of application should be when the corn ears start to silk. It should be remembered that the problem is primarily with eggs laid on the silks and the young larvae hatching from these eggs in 3-5 days.

In view of the fact that the larvae migrate down the silk and soon are concealed within the silk channel between the husks at the tip of the ear and the silk grows rapidly, it is necessary to make 3-6 applications at 2-3 day intervals for adequate control.

Sampling:--Select at random 25-50 ears from the middle row or rows from each plot. Keep 1.5-3.0 m (5-10 ft.) away from the end of each plot when sampling the ears. Each ear should be carefully examined for earworm damage and recorded. The data should be recorded as "percent ears infested".

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Fall Armyworm, *Spodoptera frugiperda* (Smith)

The fall armyworm, *Spodoptera frugiperda* (Smith), is often found associated with corn earworms and will generally be controlled in the sweet corn ear with the same sprays used against earworms. However, there are some important differences in habit that make the fall armyworm a special problem at times.

Quite often, especially following cool, wet springs, tremendous fall armyworm outbreaks occur making crop protection almost impossible. Unlike the earworm, which lays its eggs singly for the most part, the fall armyworm deposits up to 100 or more eggs in clusters. Then, too, earworms seldom become numerous enough to seriously damage young sweet corn whereas fall armyworms may completely destroy a planting within a short time after plant emergence. Brett (1953), working in North Carolina, has stated that the fall armyworm is the limiting factor in the production of late sweet corn in that area. The same is true for Virginia.

No attempt will be made to discuss plot size or equipment for treatment once the silk stage is reached since the techniques for earworm control will be applicable. However, due to the habits of the fall armyworm in feeding deep in the whorls of the young sweet corn plant, it will be necessary to apply chemicals from an overhead boom directly above. Harrison et al. (1959) and Reed (1959) were among the first to recognize the possibility of using granulars on sweet corn.

In most sweet corn areas it will be necessary to maintain a 2-3 day or shorter application schedule after silking begins.

Sampling:--Make direct counts of armyworms or armyworm injury in 10-50 corn plants (Harris 1961, Janes 1974, Reed 1959). Henderson et al. (1962) point out the necessity of unrolling the leaves and thoroughly examining the whorls. If the plants have been rather severely injured prior to treatment, be sure to base the records on fresh damage. Foliage injury ratings may be useful also.

Count the armyworm infestation in samples of at least 25 ears/plot (Bowman and Young 1969, Janes 1973). Carefully observe and record the degree of injury into the same classes as used for earworms.

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Corn Flea Beetle, *Chaetocnema pulicaria* Melsheimer

Very little literature is available on the control of the corn flea beetle, *Chaetocnema pulicaria* Melsheimer. This pest is important for two reasons: 1) It may completely destroy young corn seedlings by direct feeding; and 2) Overwintered beetles carry bacterial wilt (Stewart's disease) within their bodies and transmit it to the corn plants, where it is picked up by uninfected beetles who may carry the disease to other healthy corn plants.

Robert (1955) states that "the growing of resistant varieties is the only practicable way of controlling bacterial wilt." However, at about this same time Adams and Chupp (1954) and Luckman (1955) demonstrated that flea beetle control with insecticides would definitely reduce Stewart's disease in sweet corn.

In determining efficiency of insecticides, plot size need not be large but, due to the activity of infectious beetles, each plot should be isolated as much as possible from other treated areas. Henderson et al. (1962) treated 3 row, 15.2 m (50 ft.) long areas but had each plot bordered by up to 6 adjacent untreated rows.

Sampling:--Count the number of flea beetles on 25-100 sweet corn plants/plot. Henderson et al. (1962) used a Hills' sampling cage in determining flea beetle populations (Hills 1933).

Later in the season rate the incidence of bacterial wilt. Be sure to familiarize yourself with the symptoms as they are described by Robert (1955).

Take yield records, noting number, weight, size and general conformation of the ear. Measurements as to plant height and observations on general condition may be helpful.

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European Corn Borer, *Ostrinia nubilalis* (Hubner)

The European corn borer, *Ostrinia nubilalis* (Hubner), is often associated with corn earworms and generally will be controlled in the sweet corn ear with the same sprays and schedule used against earworms. There are some important differences in habit that make the corn borer a special problem in certain areas.

The European corn borer moths, in contrast to the corn earworm adult which lays its eggs singly for the most part, deposits its eggs in clusters of up to 50 on the undersides of the leaves. The young worms bore into various parts of the plant, ears included, and often cause the stalks to break and ear section to come in contact with the ground. Unless the corn borers are controlled, complete losses of sweet corn plantings may occur, especially in late summer in the southeastern states. Damage to the ears may be especially critical since the borers often feed along the entire length of the ear, rendering it entirely unfit for marketing or processing.

No attempt will be made to discuss plot size or equipment once the silk stage is reached since the techniques for earworm control will be applicable. However, due to the habits of corn borers in feeding deep within the whorls of the young sweet corn plant, it will be necessary to apply chemicals from an overhead boom directly above the row. Harrison et al. (1959) and Reed (1959) were among the first to recognize the possibility of using granulars against sweet corn pests.

In most sweet corn areas it will be necessary to maintain a 2-3 day application schedule after silking begins. Earlier in the season, applications may be based on light trap collections of moths, the number of egg masses or egg hatch. Harrison and Press (1971) have reviewed the literature on timing of treatments for corn borer control and conclude that those who have worked with this phase have many points of view and have approached the problem from many aspects. From this it would appear unwise to attempt to establish definite overall guidelines. Instead check local practices for the area concerned. Pest management groups working with corn borers should be able to give helpful advice.

Sampling:--Make direct counts of corn borers and borer injury in 25-100 sweet corn plants (Harrison and Press 1971, Hudson 1962 and 1963). Dissect the plants and record the number of larvae, total number of tunnels and number of infested plants.

Count the corn borer infestation in samples of 25-100 ears/plot. Carefully observe and record the degree of injury into the same classes as used for earworms.

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TOMATOES, *Lycopersicon esculentum*

Tomato Fruitworm, *Heliothis zea* (Boddie)

The tomato fruitworm, *Heliothis zea* (Boddie), is the most serious pest of tomatoes in the United States and is especially damaging in the southern areas. The fruitworm is a most versatile insect and is also known as the corn earworm and cotton bollworm. Due to its overall importance, suggested practices for this pest will be emphasized. Other insects and injury may be sampled and recorded using essentially the same test method. Both foliage sprays and systemic granulars applied to the soil should be evaluated. The specialized tomato growing procedure of pole culture is covered under Tomatoes, Poled.

The following test methodology to determine the efficacy of insecticides to control tomato fruitworms on tomatoes is very similar to the method previously described under Cruciferae and Head Lettuce - Aphids and Thrips. Only the modifications of that method are noted below.

Experimental Design:--Plot size may vary greatly, depending on the anticipated uniformity of infestation and population density. Unpublished data at the Virginia Truck and Ornamentals Research Station, Painter, Virginia, indicates that single row 13.7 m (45 ft.) long plots with adjacent untreated rows are entirely satisfactory but would approach the minimum size. There is little evidence to indicate that the buffer row was really necessary when the tomatoes were planted in rows 1.8 m (6 ft.) apart. Harding (1971) favored plots two rows wide and 10.7 m (35 ft.) long. Middlekauf et al. (1963) used larger plots, 10 rows 1.5 m (5 ft.) wide by 15.2 m (50 ft.) long, when treatments were made in a commercial field. Shorey and Hill (1963) obtained good results in commercial fields with plots approximately one-half the size of the above.

Application and Equipment:--Hofmaster and Waterfield (unpublished data at the Virginia Truck and Ornamentals Research Station, Painter, Virginia) have utilized a Hudson Porta-Power high pressure sprayer, equipped with 37.9 liter (10 gallon) milk cans, in applying tomato insecticides. Application was at 935.4 liters/ha (100 gallons/acre) in 1.8 m (6 ft.) rows at 17.6 kg/cm^2 (250 psi) with 6 nozzles/row. Some workers have gone to the other extreme, e.g. Harding (1971) treated with a CO_2 tractor mounted sprayer operating at 2.1 kg/cm^2 (30 psi) and delivering 40.2 liters/ha (4.3 gallons/acre).

Due to the many variations possible in spraying techniques on tomatoes it would seem rather useless to attempt to standardize, especially in field scale plots. The most practicable end results for large plots will be obtained by utilizing commercial spray practices best adapted to the area concerned.

Granules may best be applied with a commercial granular applicator specially adapted for direct seeded tomatoes or transplants. Be sure to place granules in the same relative positions consistently. Calibrate the granular applicator carefully for each formulation and rate and then plant the tomatoes directly without resetting.

See also Cabbage Looper - Cruciferae for further details on ground and aerial applications.

Sampling:--Make direct counts of fruitworm damaged tomatoes. Fruitworms feed mainly on the tomato fruit, attacking tomatoes of all sizes. They do not usually confine their feeding to a single tomato but move from fruit to fruit. Sometimes, however, the only evidence of a nearly grown fruitworm will be a very small pinhole where the newly hatched fruitworm entered.

Treat on a 5-7 day schedule and check mature fruit for fruitworms. Since fruitworm injury is often relatively light it is advisable to select 100 or more fruit/plot. Harding (1971) sampled 200 fruit/plot while Shorey and Hill (1963) checked over 2000 tomatoes/plot.

Fruitworms may destroy young tomatoes. If this situation exists, count the total number of infested fruit/10-25 or more plants/plot and remove the small, infested tomatoes as they are observed.

Take yield records and record both worm-free and infested fruit from entire plot or representative area therefrom and convert yields to metric tons/ha or tons/acre.

Colorado Potato Beetle, *Leptinotarsa decemlineata* (Say)

Tomatoes are not favorite host plants of the Colorado potato beetle, *Leptinotarsa decemlineata* (Say), but suffer extensive damage in certain areas, especially in the South where the tomatoes are often transplanted or seeded before the potatoes emerge. The hungry overwintered beetles seek out the young tomato plants and feed and lay eggs. Later, about the time the tomatoes mature, the potatoes are harvested and the beetles, forced to seek food elsewhere, often feed on the tomato fruits and foliage.

Sampling:--Count the number of potato beetle larvae or adults/10-25 plants. Observe fruits at harvest for feeding injury. Take yields from entire plot or representative area therefrom and convert to metric tons/ha or tons/acre.

Potato Flea Beetle, *Epitrix cucumeris* (Harris)

Overwintered potato flea beetles, *Epitrix cucumeris* (Harris), are often present at tomato transplanting or direct seeding as in the case of the potato beetle. Flea beetle damage by both adults to foliage and larvae to roots can be very severe and actually kill the transplants or direct seeded tomatoes. Direct seeded tomatoes are especially vulnerable and plantings may be completely destroyed in several days.

Sampling:--Select at least 25 leaves/plot and count the flea beetle feeding scars thereon, using the same technique as described by Hofmaster et al. (1967).

In direct seeded tomatoes, count the number of injured plants/10-25 samples/ 0.305 m (1 ft.) of row. Stand counts may be needed where infestations are severe. If the plants have several leaflets, it may be possible to check feeding scars on 100 or more leaflets/plot. On calm days, actual counts of beetles/10-25 samples of 0.305 m (1 ft.) of row may be possible. Use of a special sampling cage similar to the one developed by Hills (1933) will be helpful.

Take yields from the entire plot or representative areas and convert to metric tons/ha or tons/acre.

Aphids

Aphids seldom kill tomato plants but often stunt them and injure the fruit clusters so that yields are reduced. The potato aphid, *Macrosiphum euphorbiae* (Thomas), is the most common species. Aphids also transmit virus diseases of tomato.

Sampling:--Select at least 25 leaves or terminals from as many different plants/ plot and count the aphids.

Take yields records; check fruit and plants for virus disease at this time. Records may be taken from entire plot or representative section; convert to metric tons/ha or tons/acre.

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TOMATOES, POLED (Fresh Market)

Tomato Fruitworm, *Heliothis zea* (Boddie) and Tomato Pinworm, *Keiferia lycopersicella* (Busck)

The following test methodology to determine the efficacy of insecticides to control tomato fruitworm and tomato pinworm on tomatoes is very similar to the method described under Cruciferae and Head Lettuce - Aphids and Thrips. Only the modifications of that method are noted below.

Crop and Location of Tests:--For the very early tests that involve "screening" only, plots can be 3 rows wide by 7.6 m (25 ft.) long. However, as the compounds are tested past the initial screening stage, larger plots are recommended. Plots 4-8 rows wide by 15.2 m (50 ft.) long should be large enough to prevent the normal movement of adult moths from unduly influencing the results between plots under normal fruitworm and pinworm pressure.

Since most commercial ground applicators treat 4 rows per swath, plots to test commercial growing applications of insecticides should be 8 rows wide by 30.5 m (100 ft.) long. The length to be long enough to harvest a representative sample of fruit.

Application and Equipment:--Hy-Boy type spray equipment with vertical booms on each side of each plant row using 3-5 nozzles (depending on the height of the tomato plants) on each boom would provide good coverage when using ground equipment. Air application equipment should be commercially acceptable.

The finished spray volume per acre would be dependent on size of tomato plants. When foliar spray is applied by small hand or large ground equipment, 378.5-757.0 liters/ha (100-200 gals/acre) will give satisfactory results. When foliar spray is applied by air, 56.8-75.7 liters/ha (15-20 gals./acre) will give satisfactory results.

The time of application should be when small tomatoes first appear on the vine.

Since the control of the tomato fruitworm and the tomato pinworm require preventive type treatments, the applications should be applied every 10-12 days until harvest, making sure to observe the waiting period from the last application to the harvest when using registered standard materials. The interval between applications is dependent upon the area in which the test is conducted. When feasible more than one time interval between applications should be evaluated.

Sampling:--Since poled tomatoes (fresh market) are harvested over a period of several weeks, the sampling of the fruit for examination should be when there are enough harvestable fruit to get a representative sample. Select tomatoes at random over a wide area of the plot so that a representative sample can be taken, but at all times keeping within a well buffered zone.

Small screening hand plots that are 3 rows wide by 7.6 m (25 ft.) long should have a fruit selection area one bed wide and 1.5 m (5 ft.) from the end of each plot. This method would provide a 2 row buffer zone on each side of each plot.

Ground plots that are 4-8 rows wide by 15.2-30.5 m (50-100 ft.) long should have a fruit selection area from the middle 2-4 rows and 10-20 ft. away from the end of each plot. This method would provide a 2-4 row buffer zone on each side of each plot.

Air plots that are 36.6 m (120 ft.) wide by 182.9 m (600 ft.) long should have a fruit selection area 12.2 m (40 ft.) wide (middle one-third) and 30.5 m-45.7 m (100-150 ft.) away from the end of each plot. This method would provide a 24.4 m (80 ft.) buffer zone on each side of each plot.

A total number of 350-400 marketable tomatoes is selected at random per each pesticide treatment, regardless of the number of plots.

Each tomato should be examined and recorded as damaged if found to have a fruitworm or pinworm larva, or if only the damage is present on the fruit. Extreme care should be taken to be sure that the damage is caused by the fruitworm or pinworm. Normally one hole caused by one larvae is enough to grade the tomato down or discard it as a "cull", so normally the number of holes or larvae per tomato are not significant enough to record unless "severity of infestation" type data is requested. The total number of tomatoes infested is recorded as well as the percent tomatoes infested.

Plants in plots treated with any new pesticide being tested should be examined at least once to determine if there is any detrimental effect on yield. This is especially important when the pesticide is applied during the early stages of plant development, such as when there are many blossoms on the vine. All tomatoes in a given area of the central part of the plot should be harvested. Marketable tomatoes should be harvested in commercial field boxes, and that number converted to "boxes yield per ha (acre)". Because poled tomatoes are harvested several times, it is recommended that more than one harvest be made for the yield records.

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GREENHOUSE VEGETABLES

Greenhouse vegetables are important high value crops in many states. Tomatoes are most widely grown: lesser crops are lettuce, cucumber, radish, cress, endive and several other vegetables. These crops are often rotated such as tomatoes in fall and spring, with lettuce as a winter crop. Spring crops of vegetable plants and ornamental or bedding plants are grown by some operators. A fall crop of tomatoes is grown on some vegetable farms where the greenhouses are used in late winter and spring for growing vegetable seedlings for early spring field plantings.

Approximately 30 species or groups of closely related species of insects, mites, slugs, snails, sowbugs, and symphylans feed on foliage or fruits, stems and roots, or destroy the seedlings (Smith 1959).

The pesticides for use on greenhouse vegetables are applied in several ways:

Sprays Equipment for applying liquid sprays varies from knapsack sprayers for spot spraying or in small greenhouses, to small portable power sprayers for narrow aisles, to stationary pumps with extensive pipe or hose lines.

Low volume pesticides are applied with special equipment and special formulations.

Aerosols Liquified gas propelled aerosols containing the dissolved insecticide in methychloride with a mutual solvent when needed are released with considerable turbulence (Smith et al. 1947, Smith and Lung 1948, Smith 1950). Mechanical aerosols with insecticide in a volatile solvent are discharged with equal turbulence by high velocity air streams from lightweight, portable equipment including such machines as the Solo, Klip-On, Florafume or Spacemaster foggers, Microgen and others (Johnson et al. 1965). Thermo-generated fogs produced from insecticides in special petroleum distillates are discharged also with turbulence by such machines as Dyna-Fog Model "70" or Flora-Fog (Snetsinger 1964).

Fumigants Toxic vapors from granular calcium cyanide scattered on aisle surfaces or from released volatile pesticides (dichlorvos) through the polyethylene tube ventilating system are further distributed by normal convection currents from the heating system or turbulators (Weigel 1926, Smith and Ota 1967).

Smokes Combustible powders containing the insecticide in a slow burning mixture generate smoke with turbulence that becomes distributed throughout the greenhouse. Smokes are especially useful for treating small greenhouses.

By methods outlined above, the greenhouse operator can program his pest management operations that require a minimum of time and maximum safety to operators and his high value crops (Fulton and Smith 1958). Minimum effective dosages against the vulnerable stages of the pest are emphasized in most control programs. Pest control in greenhouses is largely dependent upon chemicals with vapor toxicity of short duration and minimum periods of residual action which permit harvest with short waiting periods (Fulton et al. 1950). However, these vegetable crops are more sensitive to chemicals and to temperature changes when grown in the greenhouse than when grown in the field. Therefore, the greenhouse operator must recognize optimum conditions of light, temperature and relative humidity for applying pesticides.

In evaluating the efficacy of candidate pesticides for use on pests affecting greenhouse vegetables discussed in this report, the impact they may have on non-target species that may be included in integrated control programs should be determined.

Minor Pests of Greenhouse Vegetables

At least 13 species of insects and related organisms sporadically damage greenhouse vegetable crops on which they become established from neighboring outdoor crops, ornamentals, or weeds: or they are introduced on infested plants or other materials such as shipping containers.

Test methods for obtaining data for these minor pest species listed below have not been developed in this report.

Broad mite - *Polyphagotarsonemus latus* (Banks)
Citrus mealybug - *Planococcus citri* (Risso)
Fungus gnat - *Lycoria inconstans* (Fitch)
Garden fleahopper - *Halticus bracteatus* (Say)
Grape mealybug - *Pseudococcus maritimus* (Ehrhorn)
Greenhouse thrips - *Heliothrips haemorrhoidalis* (Bouche)
Mushroom mite - *Tyrophagus lintneri* (Osb.)
Onion thrips - *Thrips tabaci* (Lindeman)
Ringlegged earwig - *Euborellia annulipes* (Lucas)
Sowbug - *Armadillidum vulgare* (Latr.)
Tomato russet mite - *Aculops lycopersici* (Massee.)
White mold mite - *Eriophyes cladophthirus* (Nalepa)
Wireworm - *Melanotus* spp.

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Aphids

At least four species of aphids are commonly found on greenhouse vegetables. The foxglove aphid *Acyrthosiphon solani* (Kltb.), green peach aphid *Myzus persicae* (Sulzer), melon aphid *Aphis gosspyii* Glover, and potato aphid *Macrosiphum euphorbiae* (Thomas) cause stunting and curling of new growth, yellowing and death of older leaves. Fruits and foliage become coated with honeydew followed by black sooty mold. In addition, aphids transmit cucumber mosaic virus to tomatoes and cucumbers.

Aphids are readily controlled with soil systemics, also with aerosols, smokes, fumigants, or sprays on most crops except on dense foliage of lettuce or cucumbers. To be effective, early season control is important.

Crop and Location:--Plants of cucumber, lettuce, tomato, cress, or radish are grown in 10 cm (4 in.) pots or larger containers and infested with desired species of aphid from test colony.

For the tests, use vigorous aphid colonies, composed predominately of apterous nymphs and adults and free of parasites, predators, and fungus infections that would confound the results.

Experimental Design:--Groups of 4 or more plants, each of desired test crops and desired aphid species, may be used for systemics applied to the soil, for sprays applied with knapsack sprayer, or for spacing among other plants in greenhouse units 28.3 m^3 (1000 $ft.^3$) or larger houses for testing aerosols, mists, combustible powders or smokes, and fumigants.

Each formulation should be compared with a standard formulation of known performance and with an untreated control.

After minimum effective treatment has been established, make series of applications with natural infestations in commercial greenhouses: place pots of infected test plants at intervals to determine efficiency of control and effect on crop.

See Leafminers for other details.

Application and Equipment:--See statement under Leafminers.

Sampling:--Make 24-hour posttreatment count of dead or moribund aphids that drop from plants onto papers placed beneath the pots before treatment, also those that lodge on plant parts. Make 1-day and 3-day count for survivors.

In naturally infested commercial crop, make 1-day and 3-day counts posttreatment for mortality. Make counts at 7 day intervals for buildup of population to determine need for retreatment.

Record observations on host plant reaction such as tip burn on lettuce, chlorosis or flower bud abscission on cucumber or tomato following treatment.

Analysis and Reporting of Data:--See statement under Leafminers.

Reference

Smith, F.F. 1962. Control of Insect Pests of Vegetables. USDA Agric. Handbook #142. 25 pp.

Beetles

Spotted cucumber beetles, *Diabrotica undecimpunctata howardi* Barber, and striped cucumber beetles, *Acalymma vittata* (Fabricius), damage outdoor crops and enter the greenhouse in spring and autumn. They feed on stems and foliage of cucumber and infect plants with bacterial wilt; they also attack tomato and lettuce.

Several species of flea beetles, but especially potato flea beetles, *Epitrix cucumeris* (Harr.), enter greenhouses in spring and fall and damage young tomato plants.

Crop and Location:--These pests as adult beetles are sporadic invaders on greenhouse vegetable crops and normally do not breed on them. Control measures designed for treating entire greenhouses are therefore essential.

Experimental Design:--If a screening program for new chemicals is desired, follow procedures for rearing and testing insects under Leaf Eating Caterpillars.

For tests with sprays, select randomly located groups of 20-30 cucumber or tomato plants or comparable areas of cucumber, lettuce, or tomato seedlings that are being damaged by one or more of these pests.

For tests with aerosols or fumigants, select units of 28.3 m^3 (1000 $ft.^3$) or commercial greenhouses.

Include untreated control and a treatment with test chemical of known performance as a standard for effectiveness.

Application and Equipment:--See Leaf Eating Caterpillars.

Sampling:--Make pretreatment counts of adults present in 3 or more randomly located groups of plants in infested greenhouses.

To obtain information on mortality of beetles in treated areas, place sheets of paper or polyethylene under groups of plants before treatment. Make 24 hour posttreatment count of living beetles that are present on the plants and record those dropping onto sheets and record on basis of m^2 (10.8 $ft.^2$). The dead beetles on sheets may not reveal total mortality since insects may disperse for various distances before they succumb.

Make insect injury ratings of 1-5 on seedling tomatoes or other affected hosts 24 hours posttreatment. Fully describe leaf damage such as seedlings with injured leaves and cucumber plants with gouged stems.

Record host plant injury following application of test material 1 day and 7 days posttreatment, including foliage injury such as chlorosis, marginal burn, also flower bud abscission on tomatoes and cucumbers.

Analysis and Reporting of Data:--See statement under Leafminers.

Reference

Smith, F.F. 1959. Control of Insect Pests of Greenhouse Vegetables. USDA Agric. Handbook #142. 25 pp.

Cutworms

Several species of cutworms including the black cutworm *Agrotis ipsilon* (Hufnagel), variegated cutworm *Peridroma saucia* (Hubner), and the dingy cutworm

Feltia subgothica (Haw.) attack lettuce, cucumbers, tomatoes, and cress, especially in the seedling stage. The variegated cutworm and others known as climbing cutworms also climb older plants and feed on leaves, buds, and fruit. All hide in the soil or mulch during the day and feed at night. In the greenhouse, adults and young larvae have been controlled by aerosols containing parathion or malathion. Baits containing bran, molasses, sometimes other ingredients, and a toxicant are effective against older cutworm larvae.

Crop and Location:--For tests in greenhouses with cutworm infestations on lettuce, tomato, cucumber, or cress, select plots of adequate size to reduce influence of larval dispersal from contiguous plots.

Experimental Design:--If facilities are available, cutworm larvae may be reared and released in plots 1 or 2 days before treatment. See Leaf Eating Caterpillars for rearing methods.

All treatments should be replicated 3 or more times for evaluation of results. Also include an untreated control and a treatment with test chemical of known performance as a standard for effectiveness.

Application and Equipment:--For application of aerosols, fumigants, or ground sprays, see this section under Leaf Eating Caterpillars.

Bran baits prepared with or without molasses and with the test compound as toxicant are broadcasted late in the afternoon at rate of 11.2 to 22.4 kg/ha (10 to 20 lb/A) (Metcalf et al. 1962). It should not be scattered on the plants but directed to the ground.

Sampling:--Make direct counts of dead larvae found in soil depressions around the base of injured plants.

Make counts of cutworm-injured plants at 1 and 7 days posttreatment.

Analysis and Reporting of Data:--See statement under Leafminers.

Reference

Metcalf, C.L., W.P. Flint, and R.L. Metcalf. 1962. *Destructive and Useful Insects*. McGraw-Hill Book Co., New York. 1083 pp.

Garden Symphylan

The garden symphylan *Scutigerella immaculata* (Newport) is a widespread pest of vegetable crops, fruits, and ornamentals in 25 states and occurs both in greenhouses and out-of-doors. High soil temperatures in southern states and drier soils in areas of low rainfall limit even wider distribution of this pest. Irrigation of dry-land areas promotes further distribution of this pest (Waterhouse 1970).

Existing infestations in greenhouses are usually suppressed by preplanting soil fumigations with ethylene dibromide or D-D mixture as used for nematode control of soil sterilization with steam or hot water, but these treatments fail when the symphylans penetrate to soil depths below the zone of effective treatment or they migrate from untreated areas through drainage tiles, gravelly soil, or earthworm tunnels. They survive by feeding on organic matter from manure or decaying vegetable matter between crops. For reproduction, however, they require living plant roots of the growing crop (Shanks 1966).

Plants injured by symphylans are stunted, grow slowly or die due to the severe pruning of the root system. Soil drenches with lindane have been an effective supplementary post-planting treatment in greenhouses on both vegetables and ornamentals.

Field experiments have demonstrated that certain chemicals are highly effective in protecting crops from symphylan damage. These chemicals seem worthy of testing for effectiveness on vegetable crops in the greenhouse.

Complete control of symphylans for 18 weeks in Oregon resulted from soil treatments or by dipping bare roots and stems of broccoli plants being transplanted to the field (Berry and Crowell 1970). In Pennsylvania applications in the row or broadcast resulted in protection of corn and beans for 62 days (Gesell and Hower 1973).

Since natural infestations in greenhouses tend to be localized and populations vary, performance data may not be readily obtained. Ramsey (1971) proposed the desirability of artificially infesting experimental plots and outlined a procedure for mass rearing symphylans.

Rearing colonies of garden symphylans can be accomplished by placing 20 adults in a .947 liter (1 quart) glass canning jar with 2.5 cm (1 in.) of gravel in the bottom and loosely filled with soil at 25% soil moisture and held at 21.1°C (70°F). Fresh carrot roots are supplied twice weekly as food (Shanks 1966). In later studies, Berry (1972) used ground hemlock bark at 30% moisture and temperature of 24°C (75.2°F). By supplying both lettuce leaves and carrot roots as food, he obtained 20 fold increase in 6 months. Portions of the media containing symphylans are distributed among the plots (Ramsey 1971).

Crop and Location:--Young tomato, cucumber, or lettuce plants should be set in infested areas in the greenhouse. Radish and cress should be seeded. Plots of tomatoes and cucumbers should be 3 rows wide and 5 m (16.4 ft.) long. Plots of lettuce, radish, and cress should be of comparable size.

Experimental Design:--Symphylan populations already present may be supplemented from reared colonies to insure a uniform infestation. Allow several days time for symphylans to become distributed before treatments are applied. Each series of tests should be replicated 4 or more times in randomized block design. A known effective treatment as a standard and an untreated check should be included for comparison with candidate materials.

Application and Equipment:--Dipping roots of transplants can be done at time of setting plants in the growing sections of greenhouses. Measured quantities of drenches can be applied to the soil at the base of each plant after they have been transplanted from pots to greenhouse beds, or in a furrow beside the plants made with a wheel hoe. Granules can be applied in the furrow for band treatments with a hand shaker. Broadcast treatments on small plots can be made with a hand shaker and to larger plots with equipment generally available for applying measured quantities of granules or powders to agricultural crops. The granules can be incorporated in the soil with a garden rotary cultivator (Gesell and Hower 1973).

Sampling:--Make uniform soil samplings; 2 or more per plot, to a depth of 20.32 cm (8 in.) to include part of the root zone of the growing plants and record the living symphylans in the sample by visual examination or more accurately by flotation of symphylans by stirring the soil sample in water. Pretreatment samplings should be made in each plot. Make weekly samplings posttreatment to determine the residual effectiveness of the treatment.

Make observations on growth effects of symphylan damage on the crop and differentiate from damage due to chemical treatments.

Take yield data of harvested crops.

Analysis and Reporting of Data:--See statement under Leafminers.

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Greenhouse Whitefly

The greenhouse whitefly *Trialeurodes vaporariorum* (Westwood) is presently the most serious pest of greenhouse vegetables and ornamental crops—and is established in greenhouses throughout the United States. This whitefly does not survive the winter out-of-doors in cold climates but it breeds during the summer on vegetables in commercial fields and home gardens including squash, potatoes and tomatoes, also on numerous ornamentals and weeds. It is being distributed on vegetable and ornamental plants from greenhouses and garden centers. Flying adults reinfest greenhouse crops in the fall. Greenhouse cucumbers and tomatoes are most seriously infested because of the higher temperatures at which they are grown; but lettuce, radishes, and cress are also infested.

Infested foliage becomes yellowish-green and the plants are stunted from whitefly feeding on plant sap. Foliage and fruits are often blackened by sooty fungus that grows on the honeydew secreted by the adults and nymphs. Reduction in yields of tomatoes results from sooty mold fungus that grows on honeydew deposits, also by direct feeding damage on the foliage (Lindquist et al. 1972).

At normal temperatures for growing greenhouse tomatoes, the life cycle from egg laying to adult is about 35 days - eggs, 11-12 days; first nymphal stage, 2-4 days; second, third and fourth nymphal stages, 4 days each; and quiescent pupal stage about 9 days. Adults mate and begin laying eggs within 20 to 40 hours and continue to lay eggs daily for 30 to 40 days.

The motility of adults and their daily reproduction over several weeks results in infestations in all stages of the insect on the same plant.

Successful control of greenhouse whitefly has been dependent upon regularly timed applications of the most widely used insecticides that kill the adults, the newly hatched motile nymphs in the first instar and the sessile nymphs in the second instar. Nympns in the third and fourth instars are more resistant than younger nymphs, the pupae are highly resistant, and the eggs are little affected by most registered chemicals (Gentile 1972, Krueger et al. 1973, Smith et al. 1970, Webb et al. 1974).

Crop and Location:--For the preliminary tests to obtain data on mortality of various whitefly stadia, all plants should be grown under isolation before and after infestation and treatment.

Select a variety of tomato or cucumber commonly grown in commercial greenhouses. For preliminary tests, an excellent host plant is the Henderson bush lima bean, seedlings of which are easily grown; adult whiteflies readily oviposit on the primary leaves, and the nymphs and pupae are uniformly exposed for treatment and examination (Smith et al. 1970, Webb et al. 1974).

For soil applications of chemicals with systemic action and certain fumigants or aerosols (mechanical, liquified gas, or thermal), circumstances may make it necessary to conduct a series of applications on mixed populations in larger greenhouse units; or infested plants with whiteflies of known age can be placed at intervals throughout the compartment or experimental greenhouse unit.

Experimental Design:--Groups of infested plants with 25 to 50 insects per leaf and in desired developmental stage or age group should be replicated three or more times for each material and dosage rate. Each series of tests should include comparable groups of plants that receive (a) a known effective treatment as a standard and (b) no treatment. Treated and untreated groups of plants should be isolated to prevent posttreatment reinfestation.

Application and Equipment:--To obtain whitefly nymphs of known age and development, expose groups of plants successively for 2-8 hours to caged ovipositing adults. Continue to expose other groups at 2-3 day intervals until all stages are represented in the series. Avoid excessive egg deposition by prolonged exposure to adults and later overcrowding of nymphs, which lead to high mortality in checks. Kill adults remaining on plants after exposure using dichlorvos vapors (Smith 1970, Webb et al. 1974) and reisolate plants until time for treatment.

Sprays may be applied with 7.5 liter (2 gal.) compressed air sprayer operating at 2.1-4.2 kg/cm^2 (30-60 psi) and wetting both upper and lower leaf surfaces. Also, uniform coverage can be assured by dipping plants in the spray formulation.

Greenhouse compartments of 28.3 m^3 (1000 ft.^{3}) or larger are needed for testing materials in gas propelled aerosols using methyl chloride as propellent, mechanical aerosols with methylene chloride or other volatile solvent, microgenerators using appropriate formulations of test material, or fumigants such as granular calcium cyanide, also resin strips or other materials as corn cobs impregnated with dichlorvos (Smith et al. 1970).

Soil treatments with systemic insecticides - see statement under Leafminers.

Sampling:--Samplings to determine mortality of immature stages are made at 7 and 14 days posttreatment. Ten or more leaf discs, 1 cm (0.394 in.) diameter, cut with leaf punch or cork borer (Smith et al. 1970), entire leaflets, or half leaves (Webb et al. 1974, Krueger et al. 1973) are collected at the same relative position on treated and untreated plants. Examinations should be made with microscope and illumination so that dead and living nymphs can be differentiated. From 100 to 200 or more individuals should be included in sample counts from each treatment.

Mortality of adults on plants treated in plots on the growing crop can be made by leaf counts before and after treatment and by dead adults on squares of black paper placed beneath the plants at time of treatment (Smith et al. 1970, Webb et al. 1974). Mortality of immature stadia by leaf disc or leaflet samples can also be made on the growing crop after a series of scheduled applications have been made (Smith et al. 1970).

Analysis and Reporting of Data:--See statement under Leafminers.

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Leafminer

The vegetable leafminer (*Liriomyza* sp.) which has been identified as *L. munda* Frick (Smith et al. 1962) or *L. sativae* Blanchard (Lindquist and Krueger 1975) is a major pest of ornamentals, lettuce, tomatoes and cucumbers in northern greenhouses. The same species or closely related species damage greenhouse crops in many states. This vegetable leafminer was probably introduced into northern greenhouses from the Gulf States or California and was distributed on chrysanthemums or other ornamentals. Its wide host range includes a large number of vegetable crops, ornamentals and weeds. It does not survive the cold winters in the north but breeds throughout the year in greenhouses. Leafminers infest nearby outdoor crops during the summer, then return to new greenhouse crops in the autumn.

Leafminer injury consists of small stippled spots or punctures in young leaves caused by the female ovipositor. The oozing droplets of sap supply food for both males and females. The more conspicuous injury, however, is the serpentine mines caused by feeding larvae from eggs deposited in older leaves. A single larval mine per tomato leaflet causes a measurable reduction in yield (Wolfenbarger and Wolfenbarger 1958).

In most field experiments (Wolfenbarger 1958), insecticides have been evaluated on the decrease in numbers of mines in treated plots. Contact or residual activity of the insecticides on adults, eggs and larvae were not differentiated. Tests for control of pupae in the soil have not been successful.

For leafminer control on greenhouse crops, it is essential to establish minimum effective dosage rate and treating schedule by testing the insecticide against eggs and larvae of known age (Smith et al. 1974). Intervals between applications of 5 or 7 to 8 days will depend upon (1) residual action of test compound, (2) controlling the larva while young and before it has caused extensive damage, and (3) greenhouse temperatures that affect the developmental rate of the leafminer.

Crop and Location:--Select a susceptible variety of host crop plant for initial tests: also Henderson bush lima bean (*Phaseolus lunatus*) may be used since it is easily grown and supports high populations of larvae in primary leaves (Webb and Smith 1970). Uniform infestations can be obtained in groups of plants by exposing them to adults in a rotating exposure cage (Smith et al. 1970). Test plants should be grown in containers so that groups of plants with different aged insects can be moved to: (1) sites for precision spraying, or (2) to greenhouses for treatment with sprays, aerosols or fumigants, and (3) to isolated greenhouse units or growing areas to prevent posttreatment reinfestation. If circumstances make it necessary to select test plants from randomly infested plants in a commercial greenhouse, the leaves containing larvae in an early stage of development should be tagged and observed for results after treatment (Lindquist et al. 1973, Lindquist and Krueger 1975).

Experimental Design:--Groups of four or more pots of plants containing a total of 100 or more leafminers in each age group should be treated as a unit for each dosage level and within the range of greenhouse temperatures required for commercial production of the crop or crops involved. Three or more replications per treatment are desirable for evaluation of results.

When the minimum effective dosage has been established, make tests for phytotoxicity on host crops at increased dosage (up to 2X) at the normal temperature and also at 5°C (9°F) elevated temperature.

Follow requirements of greenhouse culture by making treatments during periods of daylight or darkness to avoid undue plant stress (water loss and wilting or leaf burn from high temperatures). Observe requirements for closing and opening ventilators for releasing insecticide vapors and controlling the temperature.

Application and Equipment:--

Foliage Application - Depending upon the test chemical and the formulation, applications can be made with knapsack sprayers operating at 2.1-4.2 kg/cm^2 (30-60 psi) and delivering 187.1-935.4 liters/ha (20-100 gallons of water/acre).

Sprays should be applied to both upper and lower leaf surfaces. For treating larger plots on the growing crops in greenhouses are specially designed equipment that includes power sprayers, micronizers, backpack mist blowers, mechanical aerosol machines, thermogenerators for fogs or liquefied gas aerosols in special containers, and nozzles for release and distribution in the greenhouse or through polytube ventilating systems. The test chemical should be incorporated in formulations required for efficient performance in any of these machines. The nature of the chemical may make it adaptable for use in some machines but not others. For example, chemicals for use in liquefied gas aerosols must be soluble in the propellent gas or in a standard non-phytotoxic solvent that blends with the propellent.

Soil Application - Systemic insecticides for control of leafminers in the foliage should be applied as granules with a special applicator that accurately measures the quantity desired for a given sized container or bed area (Smith 1952, Lindquist and Bauerle 1972).

Systemic insecticides in emulsions or solutions are applied to the soil as drenches at designated dosages for various sized containers or bench areas (Smith 1952), which will facilitate computation to kg/ha (lb/acre) dosage rates.

Sampling:--Both treated and untreated plants should be isolated from infested crops to prevent straying leafminer adults from ovipositing post-treatment. Mortality of leafminer larvae in leaves of treated plants can be determined by direct examination. Cessation of feeding and shriveling of killed larvae can be observed under low magnification one day after treatment. By examination of foliage 4 to 7 days after treatment, dead and living or emerged larvae can be determined by appearance of the mines (Smith et al. 1962). Dead larvae will be found in partially developed mines. Living larvae occur in more fully developed mines or they will have emerged and pupated at the 7-day count.

Analysis and Reporting of Data:--Data should be compared using a valid statistical test for significance such as Duncan's new multiple-range test.

Treatment performance should be compared with untreated checks and one or more highly effective insecticides that have been reported in literature or accepted as standard for commercial control.

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Leaf Eating Caterpillars

Several species of lepidopterous pests of field grown vegetable crops also are annual threats to greenhouse vegetable crops, especially in the fall when their moths enter the greenhouses and initiate infestations on lettuce, cucumbers, and tomatoes as well as other vegetables and ornamentals. It is well known that the early developmental stages of armyworms, cabbage loopers, corn earworms, and other lepidopterous pests are much more susceptible to insecticides than are older larvae (Harris et al. 1975). Early detection of infestations and prompt treatment in greenhouse vegetable crops are important for efficient control. Control programs should be based on tests against one week old larvae or, at the most, up to third instar larvae (Lindquist 1972, Harris et al. 1975, Smith 1959). By applying the pesticide at minimal dosage rates and at regular intervals against the susceptible younger larvae, possible phytotoxic effects against the more tender greenhouse crops can be reduced.

Since these pest species are also important pests of outdoor commercial vegetable crops in many parts of the country, data on promising new materials that result from field experiments should give leads to materials that may be adaptable to greenhouse crops.

Armyworms of several species, including the fall armyworm *Pseudaletia unipunctata* (Haw.) and the yellow striped armyworm *Prodenia ornithogalli* Guen, are fairly regular pests in fall crops of greenhouse vegetables. Armyworm moths enter the greenhouses in the fall. Their larvae feed on cucumber, lettuce and tomato. They also chew out large areas in the side of foliage of tomato fruits.

In recent years the beet armyworm *Spodoptera exigua* (Hbn.) has become an increasingly serious pest on both vegetables and ornamentals in northern greenhouses. It has usually been introduced on cuttings or plants from the south. Once established, the beet armyworm becomes a persistent pest, since it is less readily controlled by available pesticides than are the other above-named armyworms. If not controlled, beet armyworms continue to breed and damage crops throughout the winter.

Night flying moths of the corn earworm or tomato fruit worm enter the greenhouses in late summer or early fall and lay their eggs on tomato foliage. The young larvae feed at first on the foliage; later they cut small entrance holes in the fruits and devour the interior. A single larva may damage several fruits. Control of young larvae on the foliage has been accomplished with aerosols containing parathion and malathion (Smith 1959). Dichlorvos has also been effective.

The cabbage looper *Trichoplusia ni* (Hbn.) moths enter greenhouses in the fall. This insect is probably more widespread and the most generally serious caterpillar pest of greenhouse vegetables and ornamentals. If uncontrolled, cabbage loopers continue to breed on greenhouse crops throughout the winter. Cabbage loopers feed on foliage of tomato, cucumber, cress and radishes and are especially damaging to lettuce where they are also most difficult to control.

Prompt and regular applications of an effective insecticide are essential since young larvae and the adults of the above species are more readily killed than older larvae by parathion, malathion or dichlorvos in aerosols (Smith 1959, Harris et al. 1975).

Crop and Location:--Grow test plants of lettuce, tomato, cucumber or other crops in 10-15 cm (4-6") pots in isolation to prevent infestation by unwanted pests. To obtain caterpillars of each species, all of known age and in the same stage of development, infest groups of plants with eggs from moths reared from local infestations or captured in black lights (Harris et al. 1975). Hold eggs for hatching and rearing to one week old larvae (Lindquist 1972). Harris et al. (1975) used a more precise test method by rearing larvae to the third instar and transferring known numbers to plants one day before applying the test insecticide.

Experimental Design:--For the initial tests, groups of four or more pots of plants containing a total of 50 or more larvae in each age group should be treated as a unit for each dosage level and within the range of greenhouse temperatures required for production of the crop involved. Three or more replications per treatment are desirable for evaluation of results.

Include untreated control and a treatment with test chemical of known performance such as carbaryl as a standard for effectiveness.

Application and Equipment:--Sprays should be utilized for control of localized infestations of these pests. Knapsack sprayers operating at 2.1-4.2 kg/cm^2 (30-60 psi) and delivering 187.1-935.4 liters/ha (20-100 gallons/acre) are satisfactory for the preliminary tests on groups of infested plants: also for treating groups of 20-30 tomato or cucumber plants or comparable areas of lettuce in growing crops. For application of thermal, mechanical or gas propelled aerosols or fumigants, individual compartments with volumes of 28.3 m^3 (1000 ft.^{3}) or more would be required. For these tests, which would precede treatments in larger greenhouses, groups of plants infested as for preliminary spray tests could be placed throughout the compartment to provide infestations for mortality counts.

All tests should be conducted within temperature range required for growth of the crop and at time of day or night when host plant injury might be critical due to closing of ventilators.

Since sick caterpillars usually drop from treated plants, sheets of polyethylene or other material should be placed on the soil or mulched surface around the plants before applying the test chemical.

Sampling:--Make direct counts of 50 or more larvae from each replicate (Lindquist 1972, Harris et al. 1975) in preliminary tests. Select the time of recording mortality according to speed of action of the test chemical. Usually the counts can be made in 24 or 48 hour posttreatment.

Make insect injury ratings of 1-5 or 1-10 on host plants and carefully describe leaf damage such as percentage of leaf area destroyed or market acceptability for each category. Record number of injured and uninjured fruits in treated and check plots.

Take yield records of treated and untreated plots and take note of the extent of feeding injury to marketable parts of the plants.

Record host plant injury following application of test material, including foliage injury such as chlorosis, marginal burn, and also flower bud abscission on tomatoes and cucumbers.

Analysis and Reporting of Data:--See statement under Leafminers.

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Slugs and Snails

Several species of slugs feed on foliage of many greenhouse plants including young tomatoes, cucumber, lettuce, radish, and cress. Their injury is recognized by the ragged appearance of the foliage, gouged tomato fruits, and the presence of slime tracks. The most common species are the gray garden slug, *Deroceros reticulatum* (Muller), gray field slug, *D. laeve* (Muller), and the spotted garden slug, *Limax maximus* (Linne). Slugs frequent damp places and especially under boards, flower pots, or under any debris. Sanitation to remove their hiding places is important in reducing populations.

Use of metaldehyde baits and dusts or sprays containing metaldehyde are long standing control practices (Smith 1959). Metaldehyde is more toxic to slugs as a contact poison than as a stomach poison and exerts a greater lethal effect when the material is applied to surfaces that are traversed by the slugs. Also, metaldehyde in dusts or sprays has been more generally effective than in baits (Howitt and Cole 1962).

Weather conditions at time of treatment and following treatment affect results. Low dosages of the toxicant, metaldehyde, that immobilizes slugs and causes excessive slime production and results in desiccation during a period of low humidity will be more effective than high dosages applied during rainy periods and high humidity (Howitt and Cole 1962). Effectiveness of baits containing mesurol is influenced less by weather (Getzin 1965).

Discrepancies have occurred in the assessment of efficacy of candidate molluscicides by various workers using different techniques, different test species and with different objectives (Judge 1969). Laboratory bioassays can give only an indication of which materials should be subjected to the more realistic rigors of field evaluation (Judge 1969).

Effectiveness of a given bait is governed by the quantity consumed before paralysis sets in, there being a balance between a concentration which would produce a sublethal dose and that which would be repellent (Cole 1967). Increasing the attractiveness of a bait as by addition of beer also increases its effectiveness. Longer lasting baits by use of inert plastic foam instead of the conventional milled wheat bran are also indicated (Smith and Boswell 1970).

Crop and Location:--For the preliminary tests with baits to determine toxicity of a chemical to slugs, mix the chemical with a bait and present this bait to the animal either in the laboratory or in the plots of the growing crop. The results depend on toxicity of the chemical, on the palatability of the bait mixture, and on the feeding activity of the test animal.

The technique involving the direct introduction of a poison into the slug's alimentary canal provides a method for determining the LD 50 of any given chemical (Hunter and Johnson 1970). However, such chemicals may be of no value as a molluscicide unless it can be incorporated into an attractive bait. Attractiveness of bran in baits has been long recognized but not fully understood (Judge 1972). Attractiveness of bran is short-lived because of molds (Getzin 1965). Use of inert carriers such as plastic foam soaked in the toxicant and an attractant such as beer may lead to longer lasting slug baits (Smith and Boswell 1970).

Granular formulations or sprays containing candidate molluscicides should be distributed over flats of young peas and 20 adult *D. reticulatum* or other test species caged on each flat. Dead and living slugs and damaged pea plants should be counted at the end of one week (Judge 1972). A candidate bait in a petri dish can also be tested in a flat of caged peas or other suitable host (Smith and Boswell 1970). Crowell (1967) employed wooden boxes 45.7 x 24.2 x 8.9 cm (18 x 9.5 x 3.5 in.) with covered refuge and open arena for laboratory testing of candidate molluscicides.

Field tests may be conducted on a sod field where slug populations are uniformly distributed. The area should be divided into plots approximately 5 m (16.4 ft.) wide and 15 m (49.2 ft) long and separated from contiguous plots by a cultivated strip 1 m (3.28 ft.) wide to prevent slug migration. The treatments should be arranged in a randomized block design and with 4 replications. Granules can be applied broadcast with standard equipment (Judge 1972). Molluscicide baits can be applied at 1 to 5 m (3.28 to 16.4 ft.) intervals in similar plots. Results of efficiency are determined by placing four or more 30 cm (1 ft.) square boards on the soil at intervals in each plot and making weekly counts of slugs that congregate beneath.

Greenhouse plots of tomatoes, cucumbers, lettuce, radishes, or cress should be arranged for testing the most appropriate molluscicide formulations resulting from the program outlined above.

Experimental Design:--Slugs may be collected from the infested crop area or reared in laboratory cultures (Judge 1969). Include from 5 to 20 slugs for each material and dosage rate in each series of tests that should be replicated 4 or more times.

Each series of tests should include (a) a known effective treatment as a standard and (b) no treatment.

Application and Equipment:--Granular baits can be distributed on the soil surface by hand. Sprays can be applied with hand-pumped compressed air sprayers operating at 2.1-4.2 kg/cm (30-60 psi) or commercial equipment adaptable for this use.

Greenhouse compartments or plots in the commercial growing crop that are at least 5 m (16.2 ft.) square should be used for greenhouse tests of baits, granules, or ground sprays.

Avoid applications to the growing crop.

Sampling:--Make counts of dead and living slugs in the areas near bait stations.

Make weekly or semi-weekly counts of living slugs that congregate under 30 cm (1 ft.) square boards placed 4 per plot beginning with a pretreatment count. This method can be used in tests with baits or ground treatments with granules, dusts, or sprays.

If damage has been allowed to progress in the test plots, record number and weight of damaged tomato fruits and rate foliage injury on cucumber, radish, cress, and lettuce plants as per cent loss from slug feeding.

Analysis and Reporting of Data:--See statement under Leafminers.

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Spider Mites

In northern greenhouses the two-spotted spider mite, *Tetranychus urticae* Koch, is most common; but the carmine spider mite, *T. cinnabarinus* (Boisduval), may also be involved. The latter is a southern species that is often transported on plants shipped to northern growers.

These mites cause severe stippling injury, bronzing, drying of foliage, and extensive webbing over the entire plant. Thousands of mites in search of food may accumulate on tips of shoots, plant stakes, or hang in festoons of webs from the foliage.

Spider mite infestations are more severe during spring and summer seasons when temperatures are higher. A generation may be completed in 9 days in summer; but, at lower temperatures of fall and winter, from 12 to 16 days or longer are required. The developmental stages of spider mites consist of eggs (5 days), 6-legged protonymphs (3 days), quiescent (2-3 days), 8-legged deutonymphs (3 days), quiescent (2-3 days), and adults which may live and lay eggs for 2 to 4 weeks. Most acaricides act against only the active stages - protonymphs, deutonymphs, and adults--and require several applications at regular intervals to reduce the population. So-called ovicides may be more strictly interpreted as larvicides or prenatal ovicides (Henneberry et al. 1961).

Tepp, sulfotepp, malathion, dichlorvos, and parathion in aerosols are effective against the active stages. Parathion is the most effective because of its residual action, and less frequent applications are required. Two applications of parathion at 7 to 10 day intervals are effective. Several weekly applications of the other materials may be necessary.

Spider mite strains vary widely in their susceptibility to acaricides (Smith and Fulton 1951, Taylor and Smith 1956, Henneberry et al. 1961).

The level of resistance in the mite strain used in testing candidate acaricides may be evaluated by leaf dip or slide dip methods (Walker et al. 1973).

Crop and Location:--For preliminary tests to determine levels of resistance in the test strain, lima beans in 10 cm (4 inch) pots are satisfactory host plants.

Tomato or cucumber plants are grown in pots or containers and infested with mites by pinning leaf pieces from the test colony on 2 or more leaves of each test plant.

Experimental Design:--Susceptibility or resistance of an unknown mite strain may be determined by dipping infested beans in primary leaf stage and held in bottles of nutrient solution. Include 4 replicates per treatment and 100 or more mites with each concentration of test chemical (Walker et al. 1973). Ovicides should be tested against eggs and adult females as outlined by Henneberry et al. (1961).

Groups of 4 or more tomato or cucumber plants grown in pots and infested with mites by pinning on leaves from the test colony for use in sprays applied with a knapsack sprayer or for spacing among other plants in greenhouse units 28.3m^3 (1000 ft.^{3}) or larger houses for testing aerosols, mists, and combustible powders.

Each formulation should be compared with a standard formulation of known performance and with untreated check.

See Leafminers for other details.

After the minimum effective treatment has been determined, make a series of scheduled applications in commercial greenhouses to determine efficiency of control and effect on crop.

Application and Equipment:--See statement under Leafminers.

Sampling:--In preliminary tests involving beans with primary leaves, make 24 hour posttreatment count of adult females and immature mites on treated and untreated leaves. Mites that drop from plants, after treatment with some chemicals, should be recorded from papers placed beneath treated plants.

Mortality of spider mites on infested tomato or cucumber plants can be determined by examining leaflets or leaf discs cut with leaf punch or cork borer. Each sample should include 10 leaf discs or comparable number of leaflets taken at random from each replicate that involves 100 to 500 mites. The first sample should be taken 24 hours posttreatment. Later samples at 3, 5 and 7 days posttreatment may be necessary to determine residual activity of test compound. In houses receiving a series of treatments, make weekly samplings of discs or leaves to determine decline of mite population compared to untreated checks.

Make mite injury ratings of 1-5 on cucumber or tomato at 1 and 7 days posttreatment. Fully describe each category in rating scheme and compare with progress of injury on untreated plants. Make periodic evaluations of plant injury from mite feeding and phytotoxicity in houses receiving a series of scheduled treatments.

Analysis and Reporting of Data:--See statement under Leafminers.

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Tomato Pinworm

The tomato pinworm, *Keiferia lycopersicella* (Busck), has a long history of sporadically infesting greenhouse tomatoes in northern states and is a regular pest on greenhouse tomatoes as well as field grown tomatoes in warmer parts of the country.

The tomato pinworm does not survive out-of-doors in northern states but infests field grown tomatoes near greenhouses where infestations persist from year to year. It is transported to new areas on infested tomato plants or in fruits or in used containers.

Larvae make blotch mines in leaves, feed in growing tips and flower buds, and enter the fruit through pinholes under the calyx of ripening fruit. Effective control efforts should be directed toward the insect before it invades the fruit where it is not only invulnerable to insecticide applications but causes the greatest damage to the tomato crop.

Crop and Location:--Select a variety of tomato commonly grown in commercial greenhouses. Plants should be grown in containers and under isolation to prevent unwanted infestation with pinworms or other insects.

Less desirable, for preliminary tests, is the selection of plots in infested greenhouses where active flying adults can reinfest treated as well as untreated plants.

Experimental Design:--Groups of plants infested with 50-100 or more insects for each treatment should be replicated three or more times. Each series of tests should include comparable groups of plants that receive (a) a known effective treatment as standard and (b) no treatment. Treated and untreated groups of plants should be isolated to prevent post-treatment reinfestation.

Application and Equipment:--Expose plants for one to two days to egg-laying adults in a cage or greenhouse compartment that contains infested plants.

Application of the test materials should be made to groups of plants prior to egg hatching to determine their potential for destroying larvae before they penetrate the leaves or fruit. Residual action of test materials in sprays, dusts, aerosols and some fumigants might be effective.

To test the effect of materials against larvae within leaf mines, make application to plants (1) when the larvae are in their early instars and the mines are small and (2) against more mature larvae when mines are larger. Insecticides in sprays, dusts, aerosols and fumigants may penetrate the thin plant tissue over the larvae.

To test the materials against adults, suspend screen cages in duplicate, each containing 5 to 10 moths, in greenhouses prior to treatment with test fumigants, aerosols or dusts.

After specific action of test chemical has been determined as above, series of treatments at timed intervals can be made to plots or preferably entire sections of commercial greenhouses.

In all tests, include comparable untreated check plants or plots and a known standard chemical treatment as a basis for comparing efficiency of test material.

Sampling:--Against hatching larvae on treated plants. make observations on mines that develop indicating larvae that survived the treatment. Make direct counts of older larvae in mines or adults in cages one day after treatment and 7 days after treatment.

In tests conducted on the growing crop in commercial greenhouses where 2 to 8 or more weekly applications may be made, (a) records can be made on dead larvae in mines, (b) mines per leaf on treated plants, and (c) fruits with pinworm injuries (Lindquist 1975). Similar records should be made on replicated, untreated plots.

Analysis and Reporting of Data:--See statement under Leafminers.

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